MARCH-APRIL-1958
VOLUME IX
NUMBER 2

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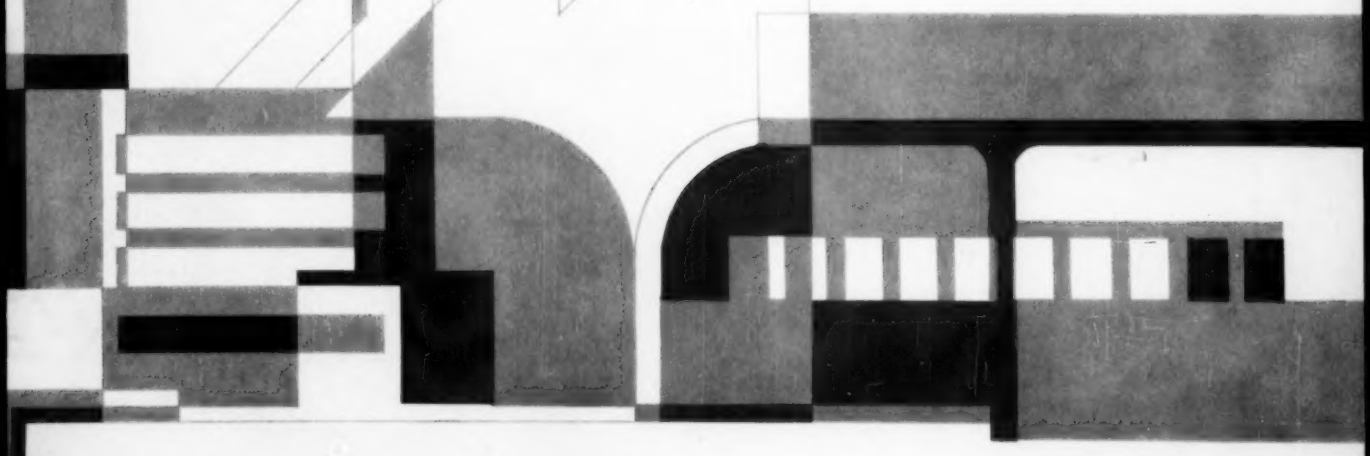

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Published Bi-monthly **• AIIE Headquarters and Publication Offices, 145 North High Street, Columbus 15, Ohio •** ***Editorial Office*****—A. French Building, 225 North Avenue, N.W., Atlanta 13, Georgia**

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Subscription Prices: $6, one year; $10, two years; single issues, $1.50.

All Manuscripts for review should be submitted with drawings suitable for reproduction to the Editor-in-Chief, Journal of Industrial Engineering, A. French Building, 225 North Avenue, N.W., Atlanta 13, Georgia.

Advertising Rates available from the Advertising Manager or any Editorial Board member. Send copy and cuts to the Advertising Manager, A. French Building, 225 North Avenue, N.W., Atlanta 13, Georgia.

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► All issues of the *Journal of Industrial Engineering* are now available on microfilm to subscribers through University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

Entered as second-class matter at Columbus, Ohio, with additional entry at Menasha, Wisconsin.

Business Ethics

by **ALEX W. RATHE**

Associate Professor of Management Engineering, New York University

Ethics are one of the hallmarks of a profession. To the Industrial Engineer who works on management problems of so many kinds, business ethics are a field of special and personal involvement.

MANAGEMENT KNOW-HOW

A SUCCESSFUL executive is master of many managerial tools. "Organization," "Planning," "Appraisal" are just a few of the examples from this tool kit of management know-*how*. There are of course many others, such as "Communications," "Decision Making," "Coordination," etc. These techniques and processes are effective in the hands of a man or woman who has the proper combination of skills, attitudes and experience to bring to bear on managerial problems.

But there is one other ingredient to executive success. It is management know-*why*. It is not only what we do and how we do things; the reason why we proceed as the case may be, has also a very significant impact on results.

In his famous Policy Declaration in Houston in 1928, Mr. Walter S. Gifford speaking for AT&T's top management, set the tone. He stated in words whose importance was recognized only years later:

> Today, management realizes that it is in the position of a trustee in which not only the stockholders but the employees and the public must be considered.

Thirty years later, this fundamental recognition is becoming the foundation on which progressive executives base more and more decisions.

It is only proper that this is so, because more powerful than the finest tool are the frame of mind, the attitude, the philosophy of the man who uses it. Ethics are the cornerstones of life, in business as elsewhere. Their presence determines whether effective techniques can bring results; their absence dooms the best instrument to ineffectiveness or failure.

Take the laws of Prohibition, for instance. Their intent was obviously constructive. The invasion of bad, often criminal thinking perverted them quickly into one of the most destructive rules conceived in recent years. It is the spirit, not just the letter of the law which gives it significance.

A discussion of ethics in business is, despite Mr. Gifford's pioneering, still a less than usual topic. Yet they constitute a challenge to all of us, particularly to the practitioners of a profession, like engineers. We are likely to make speedier progress when not just a few solitary leaders but large groups think about the problem and tackle it.

To keep this discussion within manageable bounds, we can take up only some of the requirements which ethical action imposes upon business and not the reciprocal obligations on the part of those with whom the Corporation deals. The latter, though slighted here, are of equal importance because ethics travel a two lane road.

MANAGEMENT KNOW-WHY

One of the many difficulties in this field is the simple fact that ethics are invisible. Nevertheless, they put their stamp irrevocably upon the instrument they govern. A few years ago, I watched a television show sponsored by a public utility. Out of the whole program which ran for 90 minutes, I recall just one scene which lasted for perhaps thirty seconds:

> A pen appeared on the screen, and a voice asked: "Is this something good or bad?" The first shot showed this pen signing a death warrant in a Nazi concentration camp. In the next scene, the same pen was used signing the Declaration of Independence.

I wish we could reproduce this sequence. It would talk so very much more effectively than any words. Here we have an every-day tool, a pen, literally bringing death in one instance and life in another, depending solely upon the spirit that motivates the man who uses it.

This spirit is all-pervading because it steers us—automatically. Ethics represent our instinctive faith, our beliefs. They hold the reins on every one of our actions. They permit us to live with ourselves, let us sleep at night in good conscience. They lead us, and are thus so eminently important for those who are to lead others.

With effective techniques which are applied in an ethical climate, we make progress. And progress is every manager's single most outstanding objective, progress for his company and its customers, for all associates, for everyone who comes in contact with the firm, and progress for ourselves.

PROFIT

What constitutes ethical conduct in this world today? We have to recognize, first, our obligation for contributions toward profitable operations of our company. We hold in the United States that it is sad *not* to make a profit. Profit is the economic lifeblood of the business. Without constant generation of profit, this blood drains away and the institution is doomed to die although society had, intentionally, endowed it with the possibility of a life span way beyond that given to mortals.

Some decades ago, existence of profit was the sole build-

ing stone of ethics. During the years of the "robber barons," managerial action was measured exclusively against the profit yardstick. This was a shortcoming not of the men at the helm, but of the country as a whole which was just starting its magnificent climb toward gradual recognition of additional values of life.

Today, profits are an indispensable part of business ethics. But they are recognized as merely one and indeed not as the only contribution. The other ingredients show the nature of ethics in even brighter colors.

THE INDIVIDUAL'S DIGNITY

Ethical business practice requires the executive to respect the other fellow's dignity, his integrity. Here is one of the many practical aspects of ethics. They supply every manager with the most powerful influence he could have on the people who work with him: Respect for others returns respect for oneself.

Pete, the superintendent of an apartment house in which friends of ours live, hired a man who was a very skillful gardener. As long as Benny was on the job, the lawns were well kept, trees sprouted, flowers grew in the beds in beautiful variety. But the superintendent was a man with contemptuous disregard for everyone except himself. He treated his men like slaves. The inevitable happened quickly. The good men deteriorated; they lost interest in their work. Within one year the gardens looked like an abandoned cemetery from Civil War days.

There was little wrong with the supervisory techniques which Pete used. He planned the work of his men well, checked up on their expenses, kept things on a strict schedule. But there was everything faulty with the spirit which guided him. Despite good management tools, the result was sad as the overriding impact of his attitude converted good workers into an indifferent crew of loafers.

Unethical behavior flaunts the dignity of others, imprisons their freedom. Ethical management bolsters the individual who, after all, is the sole source of action that is to benefit the firm. Every executive is the trustee of his people's individuality.

HIS GROWTH

Many examples could be cited in which socially acceptable philosophy of management furthers worker and company alike. Here is just one: It is part of every supervisor's obligation to help his men grow. It is our job to cultivate the oft-dormant potential of our people. This is one of the things which makes managers leaders.

This does not mean to propagate a state of affairs where we encourage workers to run wild, to the detriment of the firm and ourselves, or where errors are allowed to go unchallenged. It refers, however, to our attitude toward those who, in the best of intentions, make an occasional mistake. Many a time, such an error, though costly at first, can be turned into a very lucrative investment if we help the person learn from it and grow into a better associate.

OBLIGATIONS TOWARD GROUPS

Management's responsibilities in the human area are not confined to dealings with individuals. Ethics apply equally to contacts with groups. Let's look at employees as a group. Ethical considerations go way beyond problems generally classified as "labor relations" or "union negotiations." They include our attitudes to our people in many other ways.

The French have a famous saying: "Noblesse oblige." Rank indeed imposes obligations. Here is one instance.

Are we giving our workers just a minimum amount of information, holding back much pertinent data so that we can impress them, upon their near-inevitable failure, with our superior knowledge? Or are we encouraging them to ask for more data so that they can act more intelligently, on the strength of sufficient understanding?

In this manner, work will be more effective; personnel will be more content and prouder of their superiors to whom they owe the instructions which brought their success. And we, ourselves, will be happier as in addition to material progress, we will enjoy the unique prerogative of leadership: To be recognized by those with whom we work for what we are.

Or take vendors. Who has not been stung, more than once, by unprincipled companies? Yet how often have we, ourselves, acted not entirely scrupulously by stipulating as our main source of supply those firms from whom we expected to obtain some World Series tickets or a case of Scotch at Christmas or some other "innocent" remembrance. Can we expect our people to follow a straight path when they see their superiors deviate?

There are many other groups with whom business relationships go on every day. There is the community in which our firm is located. Its citizens look upon our company as a good neighbor only if it recognizes and fulfills its obligations to the town, well beyond paying taxes by chipping in on community activities.

Many a boss prides himself, justly, upon his active role in, say, a Charity Drive; he uses company facilities generously so that his group will quickly go over the top. But many a supervisor clamps down tightly upon any one of his employees who is caught when he gets a few letters typed for his Lodge's Red Cross campaign.

Space does not permit to elaborate further on our responsibilities to these and other groups, such as stockholders. But we shall attempt to suggest what business ethics demand of every manager. It can be wrapped up in one equation:

PROGRESS = PROFIT AND SERVICE

Progress is the goal of every executive. *Profit* is one mandatory ingredient. Can we sum up our obligations to individuals and groups in anything more challenging and profitable than *service?* After all, the purpose of business, as we see it today, can not be selfish gain; it has to be service to customers, to its own people, to all those who have contact with the firm.

For the business leader of today, progress spells profit and service. We need both, because profit without service is thievery, and service without profit is charity. Business is neither a member of the National Association of Thieves nor of the American Society of Welfare Agencies.

If a company makes progress, through good management in an ethical atmosphere, it is clear-cut evidence that its executives have joined together in team effort which will bring profits to the corporation as a reward for services rendered.

In this Atomic Age, there are two ways to look upon Management and upon Atomic Energy:

. . . when devoid of an ethical motivation, both are destructive; both represent conquest by material forces;

. . . on the other hand, the two can become creators of more energy when their efforts are applied in the profitable service of mankind; then they symbolize, as either should, the victory of the spirit of Man.

The Electronic Time Recorder[1] a New Instrument for Work Measurement Research

by **ELWOOD S. BUFFA**

Associate Professor of Production Management, University of California, Los Angeles

THE electronic time recorder (Figure 1) is a new instrument available for work measurement research which has unique properties of accuracy, the ability to gather mass data with minimum effort on the part of the experimenter, and minimum interaction with the subject being measured.

POTENTIAL USES OF THE ETR

The ETR was designed as a research laboratory instrument to be used where extremely short time intervals must be measured and/or where mass data are required. The author used a preliminary model of the ETR in a study of the additivity of universal standard data elements (1). This study required the isolation of very short time intervals together with the need for large samples of the data required, and perhaps would be typical of motor response studies in which the ETR would be useful. Another area of use would be in the development of time standard data where values representative of the working population are required. Here again, accuracy, the ability to measure very short time intervals, and mass data capacity are prime requirements in the instrumentation used. The ETR is visualized as a research instrument and not as an instrument for industrial work measurement.

The basic accuracy of the instrument (1/10,000 of a second) is controlled by a crystal controlled 10 KC oscillator time base which is an integral part of the instrument. The instrument was designed for convenient use by locating all displays and control switches and knobs on the slanting front panel of the console and by including a desk unit so that the experimenter may seat himself in such a position that he may read, record and control the instrument at all times.

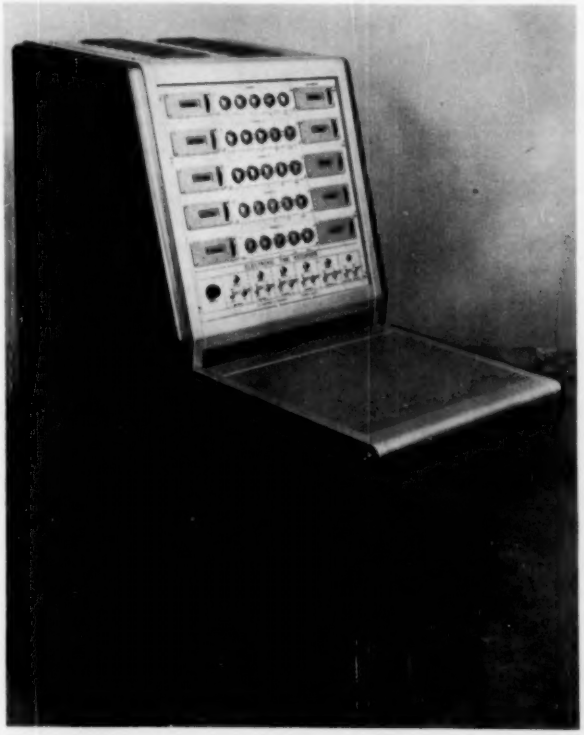


FIG. 1. The Electronic Time Recorder (ETR)

The instrument has five channels which may be used to measure either travel time or manipulation time. Either travel or manipulation time may be selected for any of the channels by a toggle switch. A close-up view of the

[1] The ETR was financed largely out of Production Management Laboratory funds and constructed in the Electronic Facility at UCLA.

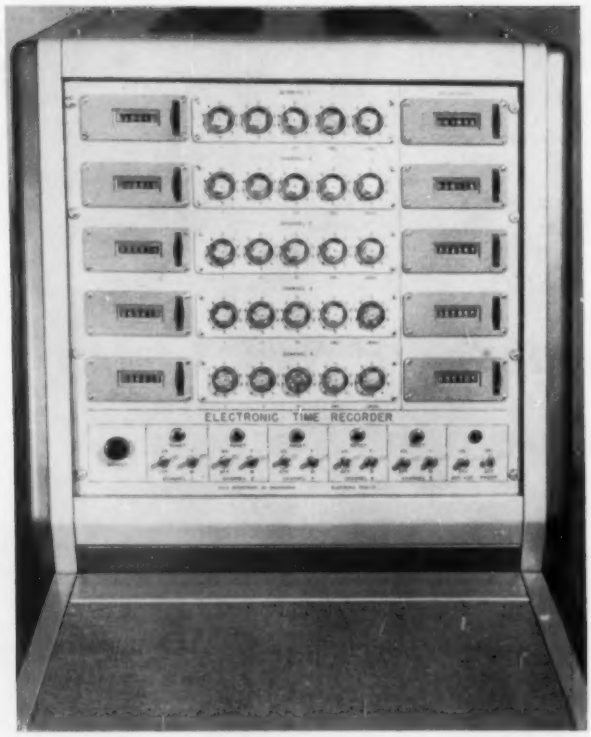


FIG. 2. Front Panel of ETR. Any of five channels may select either travel time or manipulation time by means of a toggle switch. Time is recorded in ten-thousandths of a second by a bank of counting tubes plus the mechanical counters to the left. Occurrences are counted by the mechanical counters to the right, for each channel.

front panel is shown in Figure 2, and it is seen that for each channel there is a bank of five electronic counting tubes and two mechanical counters. The mechanical counter to the right counts occurrences of the elements being measured. The bank of counting tubes plus the mechanical counter to the left record accumulated time for the number of occurrences of the element being measured in ten thousandths of a second. In reading the ETR, the last place is generally rounded off. The count capacity is 999,999 for occurrences and about 2780 hours for time. This of course is well beyond reasonable needs in work measurement research. There is minimum interaction between the ETR and the subject being measured since the ETR is actuated by subthreshold hyper audio pulses which are induced in the subject and no physical electrical connections with the subject are required even though he is a part of the electrical circuit.

HOW THE ETR WORKS[2]

A simple block diagram will serve to indicate the physical features of the instrumentation system. In Figure 3 assume that the manual task is to pick up a block of metal at station 1 and carry it to station 2. When the subject's hand touches the metal block, this is equivalent to touching the grid of a tube in the switching circuit. By virtue of this stimulus the Eccles-Jordan circuit switches and the recorder is turned on. The recorder will continue to register elapsed time until it is turned off by the switch. When the block of metal is placed at station 2, the stimulus to turn off the recorder is provided since touching station 2 is equivalent to touching the grid of a second tube in the switch circuit. The elapsed time between touching stations 1 and 2 has therefore been measured. No physical connections to the subject are necessary so that any possible interaction between the time required for the task and the instrumentation system is at a minimum.

The basic Eccles-Jordan circuit is given in Figure 4. Because of the DC feedback networks of this circuit, only one of the two triodes can conduct at any one time. The other tube is biased beyond cutoff by the feedback circuits. The Eccles-Jordan circuit therefore has two stable states of operation. Either tube V_1 or V_2 will conduct but both cannot conduct simultaneously. The potential on the grid of a tube will therefore be relatively high or relatively low, depending upon whether or not it is conducting. This makes it feasible to use the circuit as a switch by applying the potential from one of the plates to a gating circuit.

By applying a pulse of the proper magnitude to the grid of the non-conducting tube, the circuit will change state and the circuit is forced to transfer conduction from one tube to the other. This transfer takes place during an

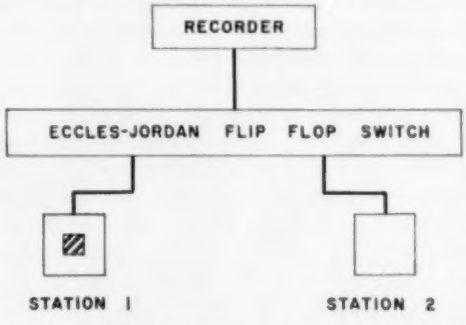
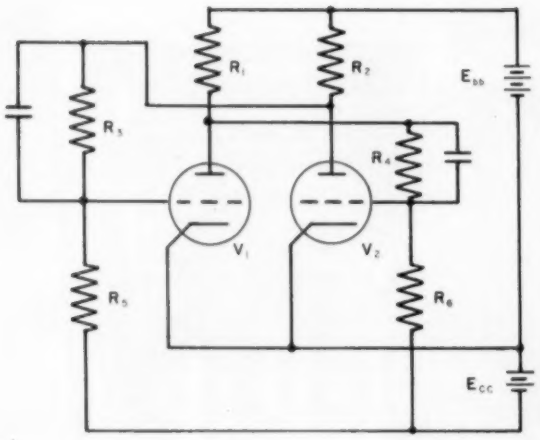


FIG. 3. Simple Block Diagram of ETR for Travel Time

[2] The ETR represents the maturation of basic ideas for work measurement instrumentation originally proposed by Christian Rand. See his paper, "A Hyper-Audio Pulse Triggered Input Device, for Work Measurements, Standard Data Sampling, and Biological Response Studies" (2). Rand's idea for a transducer with rapid electronic response and accuracy developed after his investigation of transducers formerly used in work measurement research studies, such as microswitches, photo-electric cells, etc. (3). He found variability and lag in such systems and therefore suggested the utilization of the unique properties of the Eccles-Jordan flip-flop circuit so common in computer design. This circuit has the property that if the grid of one of the tubes is touched the circuit switches. This electronic switch may be used to start and stop some time measurement device such as an electronic counter or a precision clock. In the development of the ETR it was decided to use electronic counters rather than clocks so that possible lags in the system would not be introduced by relays, etc.



E_{bb} = PLATE VOLTAGE
E_{cc} = BIA VOLTAGE
R_1 R_2 = PLATE RESISTORS
R_3 R_5 = VOLTAGE DIVIDER FOR V_1
R_4 R_6 = VOLTAGE DIVIDER FOR V_2
V_1 V_2 = TRIODE VACUUM TUBES

FIG. 4. Basic Eccles-Jordan Circuit

interval of time of 10^{-6} seconds or less for a well designed circuit. The ideal pulse should have a very steep leading edge and be of very short duration. In the ETR the input pulse is provided by a 100 KC oscillator connected to a metal plate on which the subject's feet rest during measurement. This 100 KC energy is radiated to the subject and when the subject touches metal objects which are wired to the grids of the input tubes, the triggering pulse is transmitted from the subject to the input of the ETR.

The system just described is set up to measure combinations of travel plus manipulation time. For example, in Figure 5 the system would measure the elapsed time beginning with the first contact that the subject makes with the bin of parts and ending with the first contact that the subject makes with the fixture. This group of elements might be defined as grasp plus transport loaded. The block diagram of Figure 5 shows the most important elements of the ETR. When the subject touches the bin of parts he introduces a pulse which is amplified, shaped by the squaring circuit and causes the flip-flop to open the gate and allow 10 KC energy to pass from the time base to the counting and recording circuits. When the subject touches the fixture he again introduces a pulse which causes the flip-flop circuit to close the gate and stop the flow of 10 KC to the counting and recording circuits. Meanwhile, the counting circuits have been counting the number of 10 KC pulses which have been allowed to pass the gate. Since the frequency of the 10 KC signal is carefully controlled the number of pulses counted gives the elapsed time in ten-thousandths of a second. The pulses introduced by the subject to start and stop the ETR are supplied by the 100 KC oscillator which radiates to the subject by means of the metal plate on which the subject's feet rest.

In order to measure manipulation time separately, a slightly different combination of circuits is required. This different combination of circuits is selected in the ETR by simply flipping a toggle switch. In order to measure manipulative elements, a modification of the original bystable circuit was required. This modification was called a monostable multivibrator. This circuit has only one stable state and when the circuit is not being stimulated, it is only in that state. This stimulation, of course, comes from the pulses being induced in the subject. Therefore, as long as the subject is in contact with the bin in grasping a part, the monostable multivibrator remains continuously in action and a second recorder records the time for grasp. Similarly, a monostable multivibrator and recorder could be connected to the fixture to determine the time required to position the part in the fixture.

Figure 6 shows a block diagram of the basic circuits within the ETR used for the measurement of manipulation time. In Figure 6, the time for the grasp of parts from the bin is being measured. The manipulation time circuits operate as follows: The 10 KC time base is connected to one side of the flip-flop circuit through a squaring circuit; when the subject touches the bin 100 KC is fed through another squaring circuit to the other side of the flip-flop, and this causes the flip-flop to oscillate at 10 KC. This 10 KC is fed through the gate to the electronic counter and the counter will count 10 KC pulses for as long as they are fed to it. When the subject breaks contact with the bin of parts (when grasp has been completed) the flow of 100 KC is stopped and therefore the

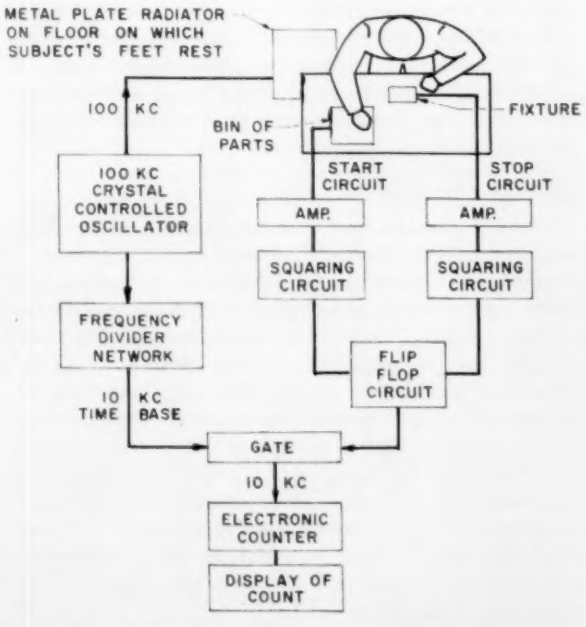


FIG. 5. Block Diagram for Travel Time

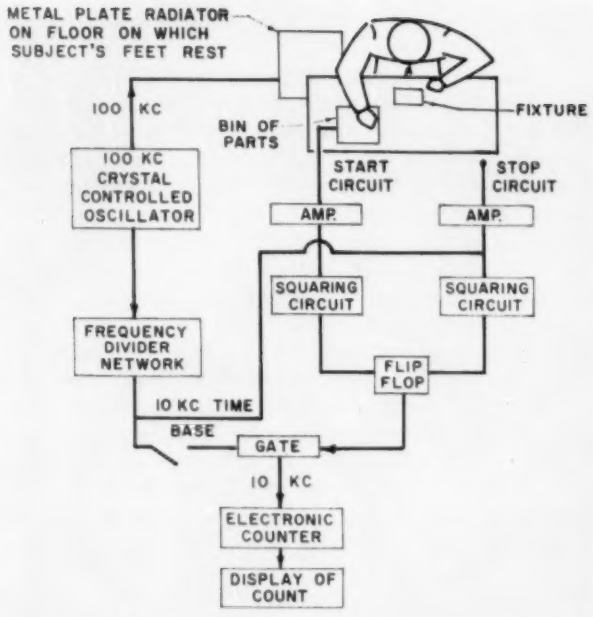


FIG. 6. Block Diagram for Manipulation Time

flow of 10 KC from the flip-flop is stopped and the interval of time recorded by the electronic counter was the time that the subject's hand was in contact with the bin of parts.

In using the ETR the main limitation is that all pick-up points must provide for electrical conduction. Thus the best contacts are provided by metal surfaces.

By use of the travel time and manipulation time circuits, a work place may be wired up to measure a sequence of elements. Flexibility in operation is obtained in the ETR by making it possible to use any of the 5 channels for either travel time or manipulation time, by means of toggle switches on the front panel. Five elements or combinations of elements may then be measured simultaneously with one ETR.

CONSTRUCTION OF THE ETR

Detailed circuit design and construction of the ETR was accomplished in the Electronic Facility, College of Engineering, University of California, Los Angeles. The design makes liberal use of plug-in units as may be observed in Figure 7. Individual circuit plug-ins were used liberally, such as amplifiers, flip-flop circuits, gating circuits, etc. In addition, groups of circuits have been developed on a plug-in basis, so that the entire oscillator circuit is a plug-in unit; the sensing circuits made up of amplifiers, squaring circuits and flip-flops, etc., are plug-in units for each of the five panels. Similarly the banks of counting circuits for each of the five channels are themselves plug-in units. This type of construction was used in an attempt to develop an instrument that would be relatively easy to maintain.

Further information about the ETR may be obtained by writing to the author in care of the University of California, Los Angeles 24, California or by writing to the Electronic Facility, College of Engineering, University of California, Los Angeles 24, California.

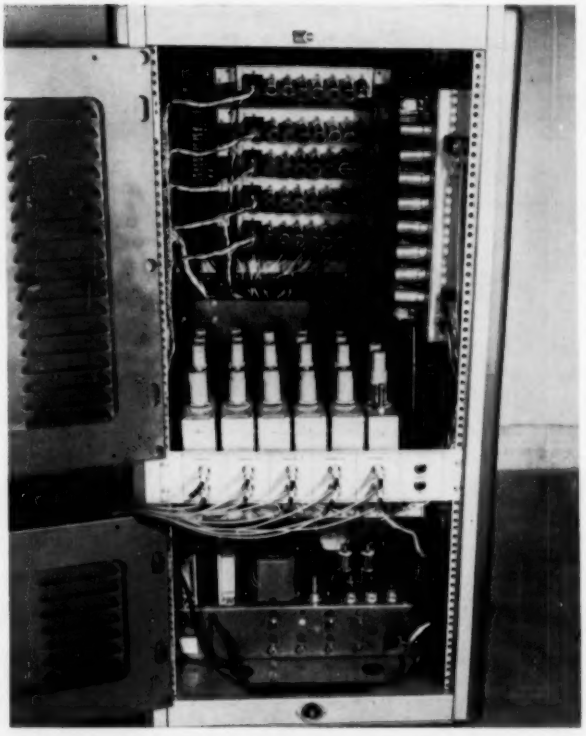


FIG. 7. Back of ETR showing construction. Plug-in amplifiers, squaring circuits, flip-flops, and gates were used. Groups of circuits were assembled on unit chassis also on a plug-in basis.

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and **HAROLD H. WEIN**

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THE scheduling of output and employment is an important topic in Industrial Engineering and management science. Linear decision rules have recently been devised to deal with this problem, and in practice they have resulted in substantial savings.[2] In this paper we explore the usefulness of such rules in scheduling output and employment in freight yards. The results are tentative and subject to obvious limitations, but they seem to indicate that these rules could be useful there. If so, linear decision rules may provide at least a partial solution to an important railroad problem.

At the outset, we should note that the model used here is a first approximation. Many factors that may be important are given only brief attention and some aspects of our formulation of the problem are tentative. We mention these difficulties below, although we do not always take them up in great detail.

SCHEDULING OUTPUT AND EMPLOYMENT IN FREIGHT YARDS

We begin this section by briefly describing 1. a freight yard, and 2. the switching function. Then the scheduling problem is considered. Note at the outset the importance of freight yards to the firm as a whole. The operation of these yards may result in about one-third of a firm's total operating costs.

1. Freight yards differ with respect to size and layout, but they all contain sets of tracks. In large yards, the track layout, usually consists of a receiving area where incoming cars are stored, a classification area where they are switched, and an outbound area where they are stored before being hauled away as a train.

2. Although it is not the only function of a yard, switching is certainly one of the most important functions. Cars arrive on incoming trains and they must be sorted out to form outgoing trains. This sorting operation is called switching. It is performed by a switch-engine that pulls a group of cars from a receiving track and shoves the cars in the group onto the appropriate classification tracks.[3] Freight yards differ greatly with regard to the number of cars switched per day. Some small yards switch fewer than 50 cars whereas a few very large yards may switch as many as 4000 cars.

In this paper, we are concerned chiefly with large yards, i.e., those that switch 1500 or more cars per day. At such yards, most engine crews are specialized; certain crews do practically nothing but switching and no other crews can engage in such work. We are interested in the scheduling of the switching output and the switch-engine crews. To fully understand this problem, it is necessary to consider the conditions under which the yard management makes decisions concerning output and employment and the costs that must be considered when a decision is made.

The general yardmaster in a freight yard usually makes these decisions. In doing so, he operates within a somewhat different framework than that typically found in manufacturing. 1. There is no possibility of producing for inventory. The railroads are a service industry and the yard can perform services only on demand. 2. He cannot reject "orders." Under normal circumstances, he must switch all cars that arrive. 3. The planning period is generally quite short. Each day, the yardmaster decides how many switch-engine crews will be used during the next twenty-four hours and how they will be allocated during the period.[4]

When he plans the switching output and the number of switch-engine crews for the next day, the yardmaster is

[1] This report is based on research supported by a grant from the Westinghouse Air Brake Corporation to Carnegie Institute of Technology. It is part of a larger project concerning the railroad industry. We should like to acknowledge the valuable assistance of C. Link, R. Nadel, and E. Saunders of the cooperating railroad, and the comments of our colleague, J. Dreze on an earlier draft.

[2] These rules were proposed by C. Holt, F. Modigliani, and H. Simon (3) and C. Holt, F. Modigliani and J. Muth (4). For an earlier work, see C. Holt and H. Simon (5); and for the proof of a basic proposition involved, see H. A. Simon (12).

[3] For a more complete description of freight yard operations, see M. Beckmann, C. McGuire, and C. Winston (1).

[4] It is commonly possible for extra crews to be hired or laid off up to two hours before the beginning of a shift. Hence, the yardmaster can often change the number of crews during one shift for the next. In practice, however, it seems that he usually plans for the entire next day and that his plans are seldom altered appreciably. A brief discussion of the problem concerning the proper planning period is contained in a following section.

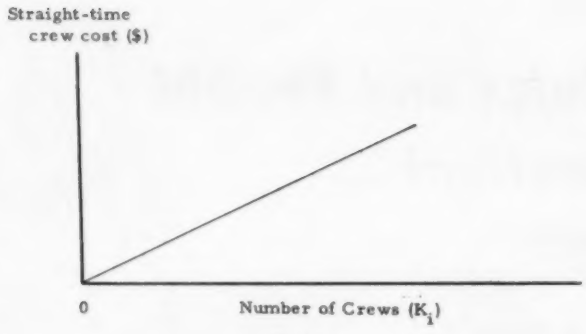

FIG. 1

uncertain about the number of cars that will arrive to be switched and the average productivity of the crews. He must forecast these variables as best he can. Crew productivity is generally treated as a constant unless climatic conditions are abnormal or congestion exists in the yard.[5] In forecasting the number of car arrivals, he often uses advance information concerning some types of traffic.[6] This information is helpful, but it by no means dispels the problem of forecasting.

Having made these forecasts, the yardmaster is ready to decide on the number of cars to be switched on the next day and the number of switch-engine crews to be used then.[7] The various strategies that are open to him, and the costs that must be considered are discussed in the following section.

ALTERNATIVE STRATEGIES AND RELEVANT COSTS

The yardmaster's decision on a given day is but one in a long sequence of such decisions. A useful way of viewing his problem is to consider how he should react to changes in the number of cars that arrive to be switched. There are, in fact, large day-to-day fluctuations in the number of car arrivals, and he may adopt many strategies to meet them. 1. He may try to vary the number of crews and the number of cars switched in accordance with variations in the forecasted number of car arrivals. 2. He may try to vary the number of cars switched in accordance with these variations; but he may maintain a constant number of crews, and use overtime to do the necessary switching. 3. He may switch a constant number of cars, use a constant number of crews, and allow the backlog of unswitched cars to fluctuate freely. 4. He may use some mixture of the foregoing.[8]

His choice among these strategies will depend on the costs associated with them. Clearly, the costs that are relevant are straight-time crew costs, overtime costs for crews, backlog costs, and costs associated with changes in the number of crews. We shall proceed to describe these costs and to represent them as functions of the decision variables.[9]

The straight-time crew cost seems to be self-explanatory. On the ith day, it is proportional to the number of crews used then (K_i). See Figure 1.

The overtime cost for crews needs no explanation. Given the number of crews (K_i) and their average productivity (P), this cost is probably close to proportional to $S_i - PK_i$ where S_i is the number of cars switched on the ith day. For $S_i < PK_i$, it is probably close to zero. This rather simple representation of the overtime cost is shown in Figure 2. In deriving the decision rules discussed below, we shall approximate this function with a smooth curve like the broken line in Figure 2.[10]

The backlog in a freight yard is the number of unswitched cars that are present in the yard.[11] *Backlog costs* are the costs associated with various backlogs. Two important costs that are included are the cost of car delay and the cost of productivity decreases due to congestion. Congestion occurs when many unswitched cars accumulate in the yard. As the congestion becomes more severe, the productivity of the crews is reduced and the costs of

[5] The productivity of the crews is relatively low when it is very cold, icy, etc. When many unswitched cars accumulate in the yard, the latter becomes congested. Serious congestion also reduces productivity because a larger part of a crew's time must be devoted to "preparatory moves."

[6] He derives this information mainly from teletype "consists" of symbol trains and from conversations with the division chief dispatcher. The former provide him with information concerning the number of cars on some important trains that will arrive up to about 7 hours hence. The latter provide him with information concerning the time at which trains will arrive.

[7] A freight yard is a service installation, and the number of cars that the yardmaster switches during the next day is not wholly under his control. In particular, he cannot switch more cars than are available to be switched. In formulating the linear decision rules, we neglect this constraint on the switching output. This seems to be legitimate so long as the rules very seldom call for the constraint to be violated. In the freight yard studied, the output prescribed by the rules violated this constraint on the following percentage of days: perfect forecast—0%, naive forecast—6%, yardmaster's forecast—0%. On the basis of this evidence it appears that the prescribed output does not violate the constraint so long as the forecasts are at all adequate. Of course, this evidence pertains only to 61 days. Another problem here is the distribution of car arrivals over time. One may take this roughly into account by linking it up with crew productivity. Still another problem revolves about the output measure used here. The number of "cuts" switched might be used instead.

[8] For a more detailed account of the ways in which a plant may adapt to fluctuations in demand, see (3, p. 3–5).

[9] The decision variables are, of course, the number of switch-engine crews and the number of cars switched. The costs that are discussed do not include all yard costs. Most of the excluded costs are essentially fixed or independent of the decision variables. Inspection, oiling and related costs can be included in the analysis but, for simplicity, they were omitted. The costs included here differ substantially from those included in our other papers.

[10] The function represented by the broken line is a quadratic function of the following form:

$$\alpha_1 S_i - \alpha_2 K_i + \alpha_3 (S_i - \alpha_7 K_i)^2.$$

[11] It is possible for a car to be switched more than once in a yard. In this case, there may be some ambiguity in our definition of backlog. For example, a car has been switched once but it must be switched again. Is it included in the backlog? We did not include it. But if it seems important to do so, the analysis may very easily be adapted accordingly.

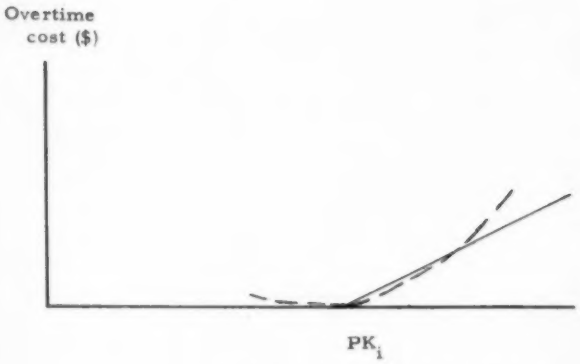

FIG. 2

unsatisfactory service increase because more cars are delayed.

Three simplifications are made in treating backlog costs. 1. We make them depend only on the size of the backlog. No account is taken of the types of cars in the backlog. 2. We make them depend only on the backlog at the end of the day. Although the backlog varies during each day, it does not seem to depart very greatly from that at the end of the day. 3. We make all costs accrue to the day when the backlog was formed. The costs may actually be spread over subsequent days, but it is more convenient to lump them together and charge them to the initial day.[12]

The cost of various backlogs is represented in Figure 3.[13] It is quite small for backlogs of intermediate size. But outside this intermediate range, the costs rise steeply. The increase on the right is due to congestion. The increase on the left is due to the fact that a portion of the backlog arrived just before the end of the day. It would be very costly and sometimes impossible to switch these cars before the end of the day.[14] In deriving the decision rules, we shall approximate this cost function with one like that (broken line) in Figure 3.[15]

Costs are also associated with *changes in the number of crews*. A substantial increase in the number of crews can often be effected only by the addition of less productive crews. A substantial decrease in the number of crews is often costly because union agreements prescribe penalties for laying off regular crews. The magnitude of these costs depends, of course, on the caliber of the extra crews and the nature of local labor agreements. At the freight yard studied below, these costs seem to be very small. But at other yards, they are likely to be much more important.[16]

LINEAR DECISION RULES

In planning the number of crews and the volume of switching for the next day, the yardmaster must consider the various costs described above. He must meet changes in traffic volume with a proper mixture of changes in the number of crews, changes in overtime, and changes in backlog. By a proper mixture, we mean one that in some sense minimizes costs. The problem of finding such a mixture is clearly not an easy one.

If the costs can be approximated by quadratic functions (such as the broken lines in Figures 2 and 3), it is possible to determine linear decision rules to aid the yardmaster in his choice. Such rules we derived for one large freight yard in the Midwest. Cost data were gathered

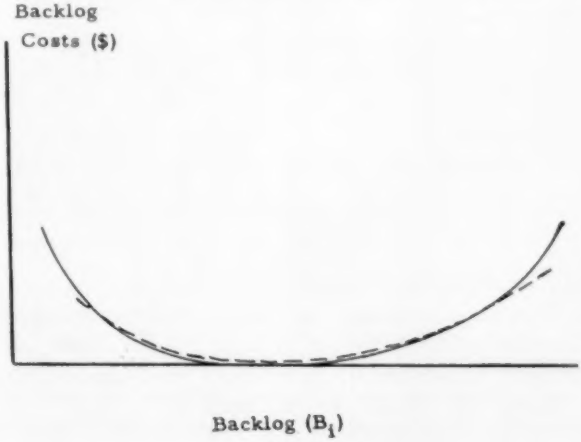

FIG. 3

[12] One may wonder why the backlog is not treated explicitly as a queue and why queueing theory is not used to determine the expected backlog and waiting time. It would seem more natural, and it might seem to avoid some of the crudeness in our handling of waiting-time costs and productivity. There are several reasons. One reason is that the relatively simple queueing models for which analytical solutions are available do not seem to fit the situation in freight yards very well (2). Monte Carlo methods would have to be used and it would be difficult to include the results in an analytical model resulting in simple scheduling rules. Moreover, if the analytical model were cast aside and if numerical methods were used throughout, it would be difficult to get any sort of general solution to the scheduling problem we consider.

[13] Some of the backlog costs are intangible, difficult to express in dollar terms and rather crudely handled. For example, waiting-time or delay costs for cars are part of the backlog costs. In the freight yard studied, a rough estimate by the yardmaster and other officials of the average relationship between waiting-time costs and backlog was used. (In simple queueing models, there are explicit relationships between expected queue length and expected waiting time (6); but they refer to the steady-state and the models do not seem to be very good approximations here (2).) In view of these difficulties, it is fortunate that moderate errors in the cost parameters have little effect on the efficiency of the rules. See (3, p. 15).

[14] The number of such cars depends on the distribution over time of the train and car arrivals. In the freight yard studied below, we relied on historical data and the yardmaster's judgment in determining the average number of cars that arrived so late that they could not possibly be switched before midnight.

[15] The function represented by the broken line is a quadratic function of the following form: $\alpha_4(B_i - \alpha_5)^2$. Of course, any constant that is also present may be suppressed.

[16] These costs are approximated by a function of form: $\alpha_6(K_i - K_{i-1})^2$.

there, and the quadratic approximations seemed to provide a reasonably good fit to the actual cost functions over the normal range. The quadratic cost function that resulted was:

$$C_t = \sum_{i=1}^{N} C_i$$

$$= \sum_{i=1}^{N} 91K_i + .85S_i - 68K_i + .0064(S_i - 80K_i)^2 + .004(B_i - 400)^2 + (K_i - K_{i-1}),^2 \qquad \text{Eq. 1.}$$

where C_t is the total cost for N days, C_i is the total cost on the ith day,[17] K_i is the number of crews used on the ith day, S_i is the number of cars switched on the ith day, and B_i is the backlog at the end of the ith day.

There are six terms on the right in Eq. 1. The first term represents the straight-time crew costs (Figure 1). The next three terms approximate the overtime costs (Figure 2: broken line). The fifth term represents the backlog costs (Figure 3: broken line). The last term approximates the costs associated with changes in the number of crews. By definition,

$$B_i = B_{i-1} + A_i - S_i \qquad \text{Eq. 2.}$$

where A_i is the number of cars that arrive to be switched on the ith day.

Holt, Modigliani, Simon, and Muth (5) (6) have shown that linear decision rules can be derived that will minimize the expected value of Eq. 1. under rather general conditions. These rules stipulate how K_i and S_i should be chosen. In the freight yard under consideration, these rules are:

$$K_i = .01091\hat{A}_i + .00118A_{i+1} - .00017\hat{A}_{i+2} - .00006\hat{A}_{i+3} + .05171K_{i-1} + .01091B_{i-1} - 4.62984 \qquad \text{Eq. 3.}$$

$$S_i = .91245A_i + .07937A_{i+1} - .01728\hat{A}_{i+2} - .00487A_{i+3} + 2.43193K_{i-1} + .91245B_{i-1} - 364.36, \qquad \text{Eq. 4.}$$

where $\hat{A}_i$ is the forecasted number of cars that will arrive on the ith day to be switched.

COST COMPARISONS: RULE VS. ACTUAL

Some evidence concerning the potential usefulness of the rules may be gathered by comparing the actual cost for some period with the hypothetical cost had the rules been used. By its very nature, this evidence can only be tentative and suggestive rather than conclusive. Moreover, the evidence presented here refers only to the one yard where data were gathered.

At this yard, a comparison of the actual and hypothetical performance was made for a two-month period in 1955.[18] To make such a comparison, certain hypothetical or assumed forecasts had to be used.[19] *First*, we assumed that the yardmaster forecasted traffic perfectly. In this case, the rule would have smoothed the switching output somewhat, but the general movement over time would have been similar to the actual movement. There would have been greater changes from day to day in the number of crews, but fewer crews would have been employed on the average. The backlog would have varied less, and it would have hovered about the optimum level. The rule's performance in terms of cost would have been better than the actual performance. Average daily costs are shown in Table 1. The overtime and backlog costs seem to be reduced sharply, and the decrease in straight-time crew costs is also substantial. Total costs are reduced by about 10 percent, the total saving amounting to about 100,000 dollars a year.

Second, we assumed that the yardmaster could not forecast traffic at all. We assumed that he forecasted for each day the level of traffic that arrived one week previous to that day. In this case, the movement over time of the switching would not have been smoothed. Greater changes would have occurred from day to day in the number of crews, but fewer would have been employed. The backlog would have varied greatly.[20] Average daily costs are shown in Table 1. Even on the basis of these naive forecasts, the rule's performance seems slightly superior to actual performance. But the estimated savings amount to only about .6 percent or 6,500 dollars a year.

TABLE 1

Comparison of Actual Costs and Costs under the Rules (Daily Costs in Dollars)

Cost Category	Actual	With Rules		
		Based on Perfect Forecast	Based on Naive Forecast	Based on Yardmaster's Forecast
Straight Time	$2313	$2232	$2248	$2216
Overtime	139	22	33	32
Backlog	72	2	207	208
Crew Change	4	7	25	32
Total	$2528	$2263	$2513	$2488

These two comparisons suggest that the indicated savings vary considerably with the accuracy of the forecasts. Hence, a *third* comparison seems worthwhile. In this comparison, the yardmaster's actual forecasts are used. For fourteen days, we recorded his forecasts of the number of cars that would arrive to be switched during each of the next four days. His forecasting errors were computed, and hypothetical forecasts with the same error pattern were formulated for the original two-month period. Had the rules been used with these forecasts, average daily costs would apparently have been about 1.5 percent lower than actual costs. Although this saving may

[17] By total costs, we mean the sum of the straight-time, overtime, backlog, and crew-change costs.

[18] For a discussion of the way in which these hypothetical costs are derived and their limitations, see (3). Note too that the costs considered here are only the costs at this one yard. Any secondary effect on other yards is ignored.

[19] No records were available concerning past forecasts made by the yardmaster.

[20] The interquartile range for the backlog would have been 280 cars. The actual performance of the yard was such that it equalled 220 cars.

appear to be modest, it would amount to about 15,000 dollars a year at this yard alone. If such a saving were realized at every large yard, the railroad we studied would gain well over $500,000 a year. (The relevant cost comparison appears in Table 1.)

Finally, the costs with the rule and perfect forecasts differ greatly from the costs with the rule and the yardmaster's forecasts.[21] (The former are about 9 per cent below the latter.) To the extent that this cost differential is a crude measure of the cost of forecasting errors, it appears that the installation of equipment and techniques to improve the yardmaster's forecasts might be worthwhile. As matters stand, his forecasts do not seem greatly superior to the naive forecasts. The costs with the rule based on his forecasts are only 1 percent lower than the costs with the rule based on the naive forecasts.) The yardmaster could never forecast perfectly, but the 9 percent differential may be some indication of the maximum saving from improved forecasting.

REACTION TO THE RULES

Though comparisons such as those shown in Table 1 are some evidence concerning the potential usefulness of the rules, it was felt that additional evidence might be obtained by getting the yardmaster's reaction to the output and employment schedule they prescribe and the problems he envisages in actually applying them. To gather this type of evidence, an output and employment schedule was computed from the rule for fourteen days.[22] Each day, the yardmaster was shown the number of crews and the switching output that were called for, and he was asked if he could see any difficulty or disadvantage in the plan. He cited two factors that in his opinion might constitute problems in using the rules.

First, he felt that fluctuations in productivity could be important and that they might limit the usefulness of the rules. Without detailed data on productivity changes, it is difficult to assess the importance of this factor. Productivity changes that can be represented as random variation about a productivity estimate should cause little difficulty (11, p. 11), and the changes arising from the heterogeneity of the output and the distribution of car arrivals can perhaps be represented in this way.[23] But the productivity changes that represent an appreciable shift in the "productivity probability-distribution" can cause considerable trouble. Hence if there are interseasonal differences in productivity, different rules should be used for each season.[24]

To understand the second problem he cited, one should note that the crew productivity is generally believed to be fairly constant (all other things equal[25]) so long as the number of crews falls in a certain wide interval. If it falls below this interval, the yard functions poorly; if it falls above this interval, productivity decreases because of interference.[26] On one day, the prescribed number of crews fell above this interval, and he cited this as a second problem. If it occurred frequently, this would indeed constitute a problem. But judging from the initial two-month period, it is an extremely rare occurrence.[27] In the very few instances where it occurs, a simple remedy may be to monitor the rule.[28]

Finally, the yardmaster was questioned concerning the problem of the proper planning period. The day is used here as a planning period, but since some changes in the number of crews can be made during one shift for the next, each shift could be used as a planning period. Possible advantages in using shifts are that the yardmaster's forecasts may be more accurate and that the problem of allocating crews and overtime among shifts is met. His replies shed only a limited amount of light on this matter. He seemed to feel that a planning period of one day was satisfactory and that the problem of allocation among shifts was of a secondary order.

CONCLUSION

An attempt has been made here to explore the usefulness of linear decision rules in scheduling output and employment in freight yards. The results refer almost exclusively to one large freight yard where a relatively intensive investigation was conducted. A comparison of the

[21] Note, however, that they are not the yardmaster's actual forecasts during the two-month period. They are based on his forecasts in a later period.

[22] Some of the cost coefficients on which this rule was based were not appropriate to this period, but they seemed to be sufficiently close to the new coefficients that no adjustment was made. The yardmaster's actual forecasts were used here in deriving the output and employment schedule.

[23] The productivity of the crews, like the productivity of service counters in queueing theory, is affected by the proportion of time they are idle. This proportion is clearly a function of the distribution of car arrivals over time. Cars are not homogeneous with regard to switching. Two groups of twenty cars may be switched, but because of differences in "cut size" and other factors, one group may take a longer time to switch than the other. Note that congestion-induced productivity changes are taken into account in the backlog costs.

[24] Interseasonal differences in productivity may occur because of climatic differences and differences in type of traffic. It might also be noted that crews are assigned to various places in the yard. The rules offer no guidance with respect to crew location, but the yardmaster seemed to think that this problem was relatively minor.

[25] Some of the "things" held constant are distribution of car arrivals, cut size, climate, degree of congestion in the yard, experience of crews, and amount of clean-up and other miscellaneous work.

[26] Essentially, interference occurs when the functioning of one crew prevents another from working effectively.

[27] With perfect forecasts, the number of crews never fell outside the interval; with the yardmaster's forecasts, it fell outside the interval once; with naive forecasts, it never fell outside the interval.

[28] The rule may be monitored by using the number of crews within the interval that is closest to the number prescribed by the rule. Note too that the rule would almost surely have to be abandoned during the few instances when a yard is seriously congested.

actual performance of the yard with the performance the rules would have prescribed was fairly encouraging. With forecasts like the yardmaster's, a substantial saving was shown but it was small percentage-wise. The yardmaster seemed very interested in the rules. He cited two problems; in both cases, there was a good chance that they would be minor.

On the whole, these results seem fairly encouraging. But note three things. First, some factors that may be quite important received little attention in the model. For example, switching takes place in a time dimension that is only partially taken into account. Some cars may have to be switched by a certain time to make proper connections, and the switching rate may have to hit peaks during the day. Second, some aspects of the model may not be entirely satisfactory. For example, the treatment of switching output as strictly a decision variable and the handling of productivity and car-delay costs seem crude at best. Third, the estimates of the cost coefficients are sometimes subject to considerable error.

Of course, in any simple model, some factors must be given limited treatment and some aspects of the formulation seem crude. Discussions with railroad officials seem to indicate that our treatment of the problem is reasonably satisfactory to the extent they can judge. In the last analysis, the test must be the performance of the rules under operating conditions. Until such a test is conducted, no really informed judgment can be made. What is needed at this point is a combination of such tests with a refinement of the model at those places that seem most important in the light of the tests. The refinement that would be required would probably not be too difficult; the difficult thing now is to know if, and where, the refinement should occur.

To conclude, we feel that linear decision rules might be used effectively in freight yards and that they might in this way contribute to the solution of an important railroad problem. But until some operating tests are conducted, no final judgment can be made.

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On Calculating the Rate of Return on an Investment

by **R. O. SWALM**

Associate Professor of Industrial Engineering, Syracuse University[1]

THIS is an allegorical tale concerning a very capable young Industrial Engineering student. It must be allegorical, for every engineer knows that the last group of very capable engineering students to be graduated were those in his own class.

Anyway, this very capable student—I'll call him Ole Ødegård since I'm writing this in Norway—became quite puzzled about midway through his first course in "Engineering Economy." In this course, Ole's instructor had —rather rigorously, it had seemed—developed a formula expressing the relationship between the cost of an investment, its final salvage value, the uniform annual net income from that investment, and the rate of return (expressed in decimal percent). This formula, which was confirmed in his text book (he was using Grant's *Principles of Engineering Economy*) was

$$R = (P - L)\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right) + Li \qquad \text{Eq. 1.}$$

Where:

R = Annual net return, in dollars
P = Amount of investment, in dollars
L = Final salvage value, in dollars
n = Life of investment, in years
i = Interest earned on investment (in decimal percent)

This, it occurred to Ole, was a rather more complicated approach (even if L were assumed to be zero) than that used by another instructor, in another course. In that course, the meaning of profit and loss statement had been analyzed, and the return on the investment had been calculated as simply the annual income divided by the first cost.

"How can this be?", thought Ole. "Surely both these formulae attempt to relate the same variable, but they don't seem to describe the same relationship!"

Being an allegorical, capable student, Ole's next move was to the library to seek further knowledge. This was unfortunate, for he soon found things worse rather than better. In the Fall, 1956, edition of *The Engineering Economist* he found, in an article by Stephen T. Heineman, that the Armstrong Cork Company calculates the rate of return on an investment as the annual income divided by the *average* investment (or one half the original investment if the salvage value is zero.)

Since he was a *very* capable student he went on undaunted, only to become still further confused when he found that Myron J. Gordon suggests (in the *Journal of Business* for October, 1955) that "The reciprocal of the payoff period is, in fact, an estimate of a proposal's rate of profit."

Being methodical as well as capable, Ole next tried to write the equations suggested by each of these methods in terms of the same set of symbols. And being *very* capable, he recognized that the annual income in the second and third methods was income *after depreciation*, whereas the R in the first method was *net dollar income*. In terms of the symbols used in Eq. 1. therefore, the "Annual income" in methods 2 and 3 would be

$$\text{Annual Income} = R - \frac{P - L}{n}$$

if straight line depreciation were assumed (and Ole hated to think of the complications introduced by any other assumption).

After some thought and pencil pushing, Ole looked down on a sheet of paper that said

Can these be the same?

$$\text{Method 1} \quad R = (P - L)\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right) + Li \qquad \text{Eq. 1.}$$

$$\text{Method 2} \quad i = \frac{R - \dfrac{P - L}{n}}{P} \qquad \text{Eq. 2.}$$

$$\text{Method 3} \quad i = \frac{R - \dfrac{P - L}{n}}{\frac{1}{2}(P + L)} \qquad \text{Eq. 3.}$$

$$\text{Method 4} \quad i = \frac{1}{P/R} = \frac{R}{P} \qquad \text{Eq. 4.}$$

He looked at this for some time, and then, being not only very capable but also a student, went out and got quite drunk.

Returning invigorated and refreshed, Ole thought that perhaps things were better than they looked. After all, he reasoned, engineers are pragmatists, let's just try an example. Perhaps, though I don't see why or how, all these apparently incongruous formulae yield substantially the same results. He had little hope for methods 2 and 3 since they seemed certain to differ by a factor of 2, but remembering, from a lecture on creative thinking, that creativity sometimes required the avoidance of negative thoughts, he went on anyway.

[1] Written while on leave and employed by the consulting firm of Asbjørn Habberstad A/S, Oslo, Norway.

"Let's see," he said, "Suppose I invest $10,000 in a project that will yield $3000 per year for 5 years. (To simplify things, let's assume no salvage value at the end of that time.) What rate of return would each of these methods yield?"

He calculated these as

Method 1: $i = 15.3\%$
Method 2: $i = 10\%$
Method 3: $i = 20\%$
Method 4: $i = 30\%$

(in method 1, he interpolated in standard capital recovery factor tables)

"Oh," said Ole, "I'll be a son of an Ødegård! This is discouraging. Even getting drunk didn't help, there's nothing for it but to use mathematics." (His phraseology here was probably due to his having spent some time in England). "Maybe," he thought, "some of these formulae can be shown to approximate others under *some* conditions, even if not in those I happened to choose."

"Let's see," he thought, "I can see no flaw in the derivation of Eq. 1. Let's work on Eq. 2."

So he wrote:

$$i = \frac{R - \dfrac{P - L}{n}}{P}$$

or

$$i = R/P - 1/n + L/nP$$

"Now what happens if we play with Eq. 1.," Ole thought, and re-wrote it as

$$R(1+i)^n - R = Pi(1+i)^n - \cancel{Li(1+i)^n} + \cancel{Li(1+i)^n} - Li$$

which simplified to $(1+i)^n(R-Pi) = R - Li$

This was as far as he got for a while, but then he was inspired to write

$$\text{but } (1+i)^n = 1 + ni + \frac{n(n-1)}{2!}i^2 + \cdots i^n$$

"Aha!" he thought (only being Norwegian, it sounded Aha!)—"If i approaches zero and if n is not too large" (you see, he was a very capable student indeed to note this latter point), "then $(1+i)^n \to 1+ni$ and thus I can substitute, getting $(1+ni)(R-Pi) = R - Li$, or

$$R - Pi + Rni - Pni^2 = R - Li$$

"Hurra!", he thought, "the R's will cancel and then, if i is not zero, I can factor it out and get

$$-P + Rn - Pni = -L, \text{ or}$$

$$i = R/P - 1/n + L/nP$$

"Well, what do you know! Method 2 gives a good approximation to method 1 *if* i is small and n not too large." And he also noted that if n *were* large, Eq. 2. reduced to

$$i \doteq R/P$$

and recalled that Eq. 1. did also!

"Intressant," thought Ole, "A two headed approximation, good for small n and i, and again for large n. But what when n is medium sized?"

But before he could answer this, another thought intruded—"But method 4 uses $i = R/P$ also, thus it too is a good approximation to method 1 when n is large!"

Returning to the question of intermediate values of n, Ole rewrote the expansion of $(1+i)^n$ as $1+ni+\Delta$ letting Δ stand for the remaining terms of the binomial expansion (and therefore a function of n and i).

He then went on, substituting and simplifying until he got

$$i = R/P - 1/n + L/nP + \Delta/n(R/Pi - 1)$$

then, substituting

$$\Delta = (1+i)^n - (1+ni)$$

and doing some algebraic manipulation, he ended up with[2]

$$i = R/P - 1/n + L/nP + \frac{P-L}{P}\left(1/n - \frac{i}{(1+i)^n - 1}\right)$$

"But," he thought, "$i/(1+i)^n - 1$ is the sinking fund factor, and I have a table of these!"

As frequently mentioned before, Ole was a fine example of what we wish we taught, and being aware of the ease with which errors creep into such algebraic manipulations, he checked the reasonableness of his results by asking if the final, or "error" term vanished when i approaches zero and n approaches infinity, as previous analysis indicated it should.

He was pleased to note that, as $n \to \infty$, the sinking fund factor and therefore the error term reduces to zero. Furthermore, both $1/n$ and the sinking fund factor (and therefore the error term as well) approach zero as n approaches infinity!

He further noted that, if $L = P$, the error term vanishes, and the equation becomes

$$i = R/P$$

and thus he knew that Eq. 1. gave the same result under these conditions.

Being not only capable and methodical, but ambitious as well, Ole decided to find, in detail, how the error term behaved for intermediate values of n. He noted that he could do this for $L = 0$ and then simply correct by the factor $(P-L)/P$ for other values of L.

He decided the most meaningful results would be curves yielding the error as a percent of the *approximate* method result vs. life.

Unfortunately, he found the simplest way to do this was to first construct a family of curves for various values

[2] Author's Note: Mr. Ødegård left his notes with me, and I would be pleased to furnish the intervening steps on request.

of n, showing the percent error as a function of the estimated rate of return and then to transpose these into the final curves, here presented as Figure 1.

At first, Ole was concerned by the fact that the error was as great as 80% for an estimated rate of return of 1%, but as he thought of this, he translated to an *actual* error of only 80% of 1%, or 0.8 percentage points, and was less concerned. Of greater practical importance, he concluded, was the fact that, for an *estimated* return of 30%, the true return could be almost 40% greater—or in excess of 40%. This could be important, particularly since this error occurs at about a 5 year life, not uncommon in industry today.

He also noted that the error is *always* in the direction of understatement. This, he concluded was desirable if an error must be made.

He then asked himself if there was an even more meaningful way of presenting his findings. He rejected the seemingly obvious way of showing true rate of return for various values of the estimated rate vs. life for two reasons. First, interpolation would be difficult and second, such curves would be valid only for the zero salvage case.

Nor was it practical to plot families of curves for various values of n, for these were found to intertwine so much that they became extremely difficult to read.

Finally, he decided that a set of curves similar to those in Figure 1, but showing *absolute* rather than percentage error would be useful. (He also noted that these curves could best be presented on log-log paper.) These curves he also left with the author, and they are presented herewith as Figure 2.

Observation of Figures 1 and 2 led Ole to some interesting observations. First, from Figure 1, he noted that the *percentage* error approached zero as i increased infinitely. And he was glad to see that this same conclusion could be drawn from a consideration of the equation he had developed, showing the error term as $(P-L)/P$ $(1/n-\text{sinking fund factor})$. For the sinking fund factor approaches zero as i approaches infinity (more rapidly as n increases, but eventually for any values of n greater than 1). Thus for very large i the error (in the zero salvage case) approaches $1/n$ and the percent error approaches $1/ni$—and thus as i approaches infinity, the error approaches zero.

"Of course," thought Ole, "the figure is for an error expressed as a percent of the estimated value, and the equation expresses it as a percent of true value, but as the error approaches zero the estimated and actual values become one and the same."

Ole also noted that all the curves of Figure 2 seemed asymptotic to the line error$\times$life$=100$ (or, if the error is expressed in decimal percent, error$\times$life$=1$). "In other words," thought Ole, "all curves lie in the region where error$\times$life≤ 1, thus the error must *always* be less than $1/n$. Furthermore, he thought, the error reduces to zero when $n=1$. So the error is not only always less than $1/n$, but can never exceed 100 percentage points!

"This too should be derivable directly from my equation for the error term" thought Ole. "Let's see, for zero salvage value the error is

$$\text{error} = 1/n - \text{sinking fund factor.}"$$

"Oh yes—since the sinking fund factor is always posi-

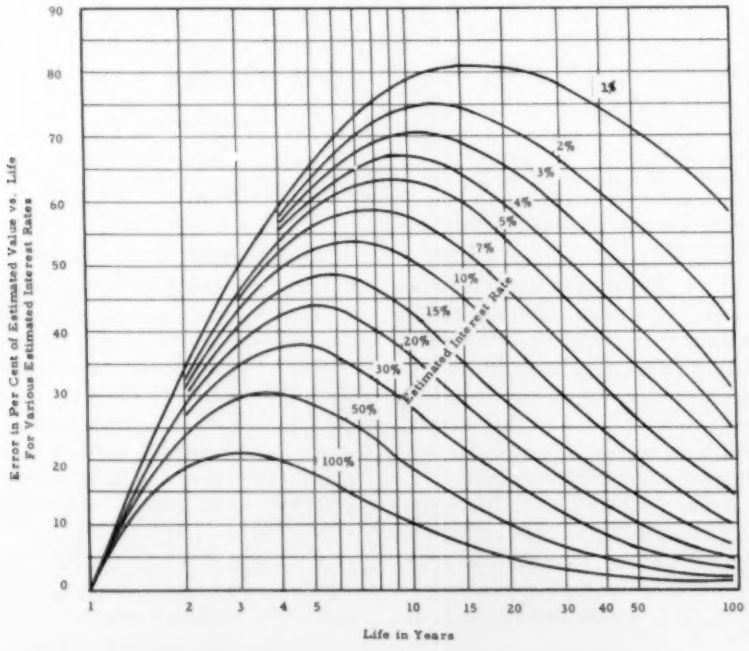

FIG. 1

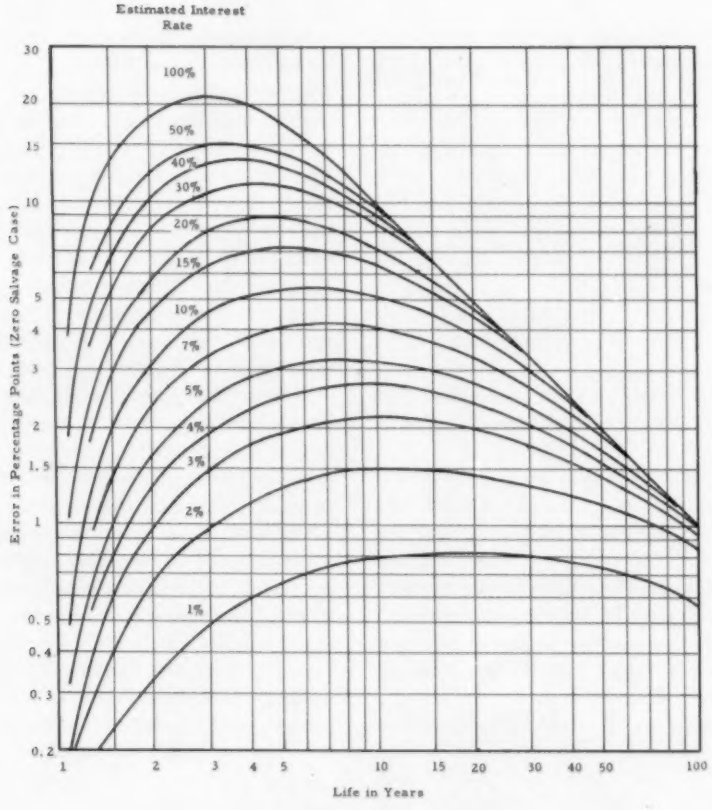

FIG. 2

tive, the maximum error must occur when this factor reaches zero, and will then be $1/n$. Furthermore, since the sinking fund factor is 1 when $n=1$, for any interest rate, the error term must disappear at this point.

Summarizing these observations, Ole noted that, in method 2:

1. The error expressed in decimal percentage points, can never exceed $1/n$; nor can it exceed 1.00.
2. The error, expressed as a percentage of either the true or estimated interest rate, approaches zero as the interest rate increases indefinitely. However, the error in most practical cases would seem to be quite appreciable.

Turning to a consideration of method 3, Ole noted that, since this method invariably yielded an estimated rate of return twice that of method 2, it could (from Figure 1) yield a correct answer only for interest rates below 1%, hardly a practical range. He redoubled his efforts to find, in the library, a justification for the use of this method, but could only find further examples of its use. He concluded he'd just have to reason this out for himself.

"Let's see," thought our Norwegian friend, "if method 3 gives twice the result of method 2, and if the error in method 2 is always positive (as it is), then method 3 will give a *more* accurate estimate of the true rate of return than will method 2 whenever the error in method 2 exceeds 50%."

Looking at Figure 1, he noted that this never occurs for rates of return, as estimated by method 2, in excess of about 12% (or, therefore, actual rates of returns in excess of 18%). For lower interest rates, there is a range of values of n in which method 3 gives a better estimate. These are (roughly)

Estimated rate of return (method 2)	*Values of n for which true rate of return exceeds the estimated rate by over 50%*
10	4 through 11
5	4 through 27
3	3 through 47
1	3 through 100+

Summarizing, for rates estimated by method 2 of under 5% and for most practical lives in excess of 4 years, method 3 can be said to yield more accurate estimates than 2. But that is saying very little, for in this range method 2 is quite poor, and besides, thought Ole, these are interest rates of little practical importance.

Of course, he thought, if error was expressed as a percent of the *estimated* value in each case, the breakeven point might appear to be at an error of 33⅓% for method 2. (This would give a *true* value 33⅓% less than that yielded by method 3). Thus this would increase the apparent range of advantage for method 3.

"But," said Ole to himself, "This would be fallacious reasoning, so surely it would not be used."

(As you see, although allegorical Ole was a very capable student indeed, he had very limited experience

in the ways of the world.)

Another line of thought led Ole to consider the fact that the *exact* uniform annual return, (R) on an investment (P) at interest rate (i), and life (n), is (in the zero salvage value case) often approximated using

$$R = P/n + P\,\frac{i}{2}\left(\frac{n+1}{n}\right)$$

solving this for i yields

$$i = \frac{R - P/n}{P/2\left(\frac{n+1}{n}\right)}$$

If, thought he, we assume that $(n+1)/n=1$ (which it approaches as n becomes infinite), this reduces to

$$i = \frac{R - P/n}{1/2P}$$

Which is the same as Eq. 3. if, in that equation, we let $L=0$.

The approximate method for find R when L is not 0 is

$$R = \frac{P - L}{n} + (P - L)\,\frac{i}{2}\left(\frac{n+1}{n}\right) + Li$$

Solving this for i (again assuming $(n+1)/n=1$), Ole got

$$i = \frac{R - \frac{P - L}{n}}{1/2(P + L)}$$

which is the same as Eq. 3.

He was, at first, concerned by the fact that he knew the approximation to the capital recovery amount used in deriving these formulae was widely used, and fairly good for low values of n and i, yet the final formulae, derived from this approximation, as he had seen, gave very poor results in many practical cases. He thought about this, and became convinced this apparent paradox was due to a number of factors. Among these were:

1. The error introduced by assuming $(n+1)/n=1$ is great for low values of n.
2. The approximation in the calculation of the capital recovery amount is poor for large n or large i.
3. In many cases approximations are irreversible. For example, in economic lot size calculations, a wide range of lot sizes will yield substantially the same cost, and therefore a rough estimate of lot size (within this range) will yield an excellent estimate of the true minimum cost. But because the curve in this region is so flat, a knowledge of the approximate minimum cost may yield a poor estimate of the most economic lot size.
4. One reason the approximate method of determining the capital recovery amount is justified is that it is widely used in conjunction with a second approximation—the use of a simple average value for increasing operating costs—and that these two approximations, being in opposite directions, tend to cancel out.

Since Ole indeed lived up to all the nice things we have said about him, it should not be surprising to find that he also remembered that, in his text, Grant cautions against this use of this approximation. Referring to Grant's text, Ole found on page 140,

> A different incorrect approximation is sometimes obtained by equating the annual net receipts to straight line depreciation plus average interest, and solving for the unknown interest rate. . . (this invariably results in an overstatement of the rate of return.

Summarizing all his findings, Ole concluded that, subject to the assumption of uniform annual income, method 1 indeed gave the correct answer.

Method 2 offers a better approximation than method 3 over a wide range of values of life and estimated (or true) interest rate. Furthermore, with the aid of the curves shown as Figures 1 and 2, Ole concluded, he could quickly determine the *true* rate of return from the *estimated* rate yielded by either of these methods.

Method 4 is valid for *large* values of n or (assuming zero salvage values) when R/P is large compared to $1/n$.

He further noted that method 4 differs from method 2 (in the no salvage case) by the addition of the factor $1/n$. Therefore, since method 2 always understates the true interest rate, thought Ole, there must be a range of n and i for which method 4 gives a better approximation than does method 2! It would therefore, perhaps be worth while, he thought, to play with this idea a bit, perhaps to draw a figure 3 showing the approximation introduced by method 4 for various values of estimated i and various lives.

But, being very wise indeed, Ole decided that, since he was going on to do graduate work, he might better save that task for a term paper, or perhaps it could even be worked into a thesis! So unfortunately, we cannot offer such a figure here.

And then, too, thought Ole, I could examine what happens in the real-world situation when the income is not the same each year—how good are the approximations then?

As Ole's mind explored this thought, he sank blissfully into a deep sleep. And there we shall leave him, dreaming peacefully of making a life work out of the analysis of functions involving $(1+i)^n$.

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Electronic Computers in Business

by M. E. SALVESON[1]

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ELECTRONIC computers often make their most important contribution precisely in that area which most determines a business' relative success, in the reasoning and problem solving processes. Because Industrial Engineers are so intimately involved in this process, they are much concerned with the growth in use of these computers in business. They, like other members of the management team, are interested in the implications of using a computer in a business. It is to this question that this paper is directed.

After a late postwar start, electronic computers are rapidly becoming one of the major advances in twentieth century management. Illustrative of their growth, a recent survey of American business found over 750 medium scale and 175 large scale computers already installed and operating. Double those numbers are on order. T. J. Watson, Jr., President of IBM, estimates that 170,000 specialists will be needed to man the computers which business will be using in 1966. It is time therefore for a reassessment—have the computers lived up to their advanced billing? What is their role in business?

Their continued rate of growth is perhaps the best evidence that business has found them to be of much value in building business efficiency and office and factory productivity. But, there are other considerations. Quite beyond simply enhancing the business processes a computer also may cause a change in the "way-of-life" of a business organization. Of course, if such change is to produce a really better way-of-life, it must be anticipated and incorporated into the business with the greatest care and understanding. Hence a computer is not a substitute for the intellectual and managerial processes to which it contributes, but rather a spur to greater skill in them.

In general, computers have lived up to their advanced billing. But one piece of evidence supporting the need for skill in managing their introduction is that there already have been some important "failures." Typically, the failures have not been due to inadequate or defective equipment. Rather they have been from inadequate preparation, insufficient understanding, or lack of participation by *all* levels of management.

A frequent and surprising result of a well managed installation is that it is accustomed to solving important business problems, the existence of which, managers initially may not have been aware. This is as it should be. As current problems are solved they are replaced by new, unanticipated ones. The computer as an important problem-solving tool accelerates this process and thus helps accelerate progress. On the other hand, the computers cannot solve "all" business and technical problems; they cannot even solve some problems as quickly and effectively as competent human judgment. Thus, the computer does not become the master problem solver; quite unlike every home's need for a kitchen sink, not every business will need a computer.

A lesson relearned in many successful installations is that a business is not a loose federation of friendly allied components, but a closely-knit and integrated system of cooperation in attaining common purposes. Since the computer often makes important changes in many segments in this system, the successful installations have been characterized by contribution from *all* levels of management in all functions of the business in integrating the computer into the business. Of course, each different level of management and each different function of the business has a different contribution, but each is indispensable.

These observations raise some of the following questions which management frequently asks when deciding on and managing a computer program. They are discussed below.

1. What problems can a computer really handle? Although this question is frequently asked an answer by analogous question is "what load can a vehicle carry?" Several examples suggest the range for different computer sizes and types.

2. How does a computer affect a business? The effects are highly variable. In some cases there is no more change than putting new spark plugs in an automobile, but in others the change is as basic as putting a jet engine in a Jenny. Two examples will illustrate the extent to which a new "way-of-life" may be fostered by a computer installation.

3. How should a company get started, and where? There are probably as many different methods and locations as there are computers installed. Not all beginning points are equally good; but, it matters less where you begin than how you proceed. That is, it is more important to avoid the "adding on" approach and to follow the "systems" approach.

4. How should a computer be organized? Like any other component of a business, the relative success of its operations is affected importantly by how and where it is located in the organization. There is no stereotyped answer as several cases will show.

5. What is the relationship to "operations research" and Industrial Engineering? OR often is termed "scientific solution of operating problems." Should it not be part of a computer program, therefore? An answer to this question requires differentiating between "means" and "ends," and the relationship of operations research to each. Several examples will illustrate this, along with a more useful role for operations research.

6. How can top management determine whether a computer program is as successful as it might be? The answer is not just in

[1] Prepared while author was a Management Consultant in the Management Consultation Service Division, General Electric Company, New York.

the number of clerical dollars saved per year. In the dynamic American economy you must run faster than that just to stand still.

In order to discuss these questions, some familiar facts on business first are cast in a special light. That is, a business is a complex of closely interrelated and interdependent activities. Each activity is performed separately by one or a group of persons, but these diverse activities complement and depend upon each other to achieve the common purposes of the business. They often are called by their functional names, such as marketing, manufacturing, engineering, including their subfunctional specialties, such as production scheduling, inventory records keeping, or other. The outputs of any one of these activities are the inputs to many others and they depend upon each other for timely and full cooperation and supply of necessary inputs. "Best" performance for any one of these activities is much less important than best performance for the whole business as measured in profits, return-on-investment, customer acceptance or other. Thus, "best" performance in, say, cost accounting is when it contributes outputs of information at such cost as makes the business most effective.

These activities are connected together in networks in order to perform certain business processes. There is one network for each process, as follows:

1. Business "planning" network.
2. Current "operations" network.
3. Business "learning" network.

The planning network is concerned with devising and designing tomorrow's business, i.e., the business scope, objectives and plans. It includes functional plans such as product scope, facilities plan, financial plan, plant expansion and location plans, capital budget (18). In order to carry out the planning process for the business, the planning network interconnects activities each of which plan some phase of tomorrow's business, such as market research, product planning, design engineering, manufacturing engineering. Each helps develop the business plan by contributing its special functional knowledge, and, in turn, each derives from that business plan further guidance in pursuing its own work.

The current operations network interconnects persons who perform "today's" operations. These are engaged in such activities as the selling, inventory control, production control, payroll, inspection, accounts receivable and accounts payable. The learning network analyzes past business and includes, for example, quality control, cost accounting, sales analysis, management audits and personnel evaluation. It seeks to learn from past experience and makes available new knowledge and insights to others so they can improve both planning and current operations. It often connects closely to planning through research studies.

The preceding trichotomy of business into the three processes and their corresponding networks facilitates analysis of the business, particularly for selecting and designing the data processing equipment into the business. The result can be to provide each member of the business with timely information which he needs for effective planning, decision-making, and action-taking in his job. In general, it is characteristic of all three networks that most of an employee's work contacts are with others in his same network. For example, product planning has much interaction with market research, product engineering, and production planning, but little with inventory control, accounts receivable or factory supervision. Also, the top managers do not participate in the activities associated with any one of these networks. Rather they provide decision criteria and limits so that each member of the networks can plan, decide and act in his job in the furtherance of the company objectives.

It is a prime characteristic of current operations that decisions and actions must be performed with timeliness and with continuity. Customers must be served whenever requested. Sales efforts must be coordinated closely and continuously with production; inventories need to be regulated continuously or they suffer from lack of timely information or decision. On the other hand, the decisions and actions in current operations usually do not require analysis of large numbers of complex alternatives. Thus, operating decisions usually can be streamlined and preplanned. Risk and commitment in such decisions are usually relatively less. Rapid communication among the activities in the network is essential to timeliness; to this end communication via a common language medium is especially helpful. "Business planning" has a different set of requirements. Moment-to-moment timeliness and continuity are not so important. Deadlines usually are more distant, though often they may be of greater dollar importance. Problems associated with business planning usually require more extensive consideration of alternatives, so much that in some cases the work of business planning involves basic "research." The risk and commitment associated with business planning decisions usually are large and become, when made, relatively inflexible, as, for example, the decision to build and the design of a new plant or a new product. The rapidity of communication is less important; the smaller volume and tentative character of the information make a common machine language also less important.

The essential requirement of "learning" is to do so as quickly, as fully and as inexpensively as is possible. However, considerable care is required to assure that there is an optimum balance in these regards. For example, one of the large hidden hazards with modern electronic data processing is to prepare too many reports too frequently and in too much detail. These should be determined so that the frequency and detail of the reports "match" the detail needed to understand and the time of correction in the situation. These may range from a few minutes to several years. For example, in many high-volume flow situations, a very quick detailed analysis of

quality for process control is essential to efficient operation. On the other hand, there would be little meaning or use in frequent, detailed reports of shop operations in measuring of the effectiveness of the top manager of a business.

The top managers' role in the three networks described above is that they ordinarily do not participate personally. That is, ordinarily they do not make the sales, do not schedule production, do not purchase the material for manufacture, do not compute or sign the payroll checks, do not design the product, do not interpret quality control reports. It is not that these decisions and actions are unimportant. Instead, they provide, through negotiation and design, the objectives and criteria for planning, decision-making, and action in each of these activities so that the personnel can perform their work in such manner that the business objectives are achieved.

So long as any middle manager's decisions or actions conform to these objectives and criteria, there is little need for participation by the top managers. However, when any situation arises which causes a departure from these, it becomes necessary for top management participation in the decisions and actions, primarily for the purpose of providing new objectives and criteria. In any case, the greater futurity of the work in business planning often makes it more difficult to state objectives and criteria which will remain valid under the changing conditions. Thus, it often is necessary for the top managers to participate in or make business planning decisions more frequently, than it is in the current operations work. For example, in one business the top management had a policy that 95% of all sales orders must be filled at the time the orders are placed. This policy directly implied certain levels of inventory be kept, and certain machine tool capacities be maintained. So long as policy on meeting sales orders was satisfied by the operating personnel in marketing and inventory control, no questions on inventory level need be referred to the top managers. However, when branch warehouses were planned, then the level of service and quantity of inventory required for the different levels of service under different locations of these warehouses were reconsidered. The result was top management reappraised its service and delivery objectives as part of the planning process in arriving at a new warehouse system.

APPLICATIONS IN CURRENT OPERATIONS

Presently most "business" applications of computers are in the current operations network. To the extent that it is possible, the various data handling equipments in that network are often linked together through the medium of a common machine language. This is often termed "integrated data processing." For the most part these applications do not involve delegating important or complex decisions to the computer. Rather the computer and associated equipment perform only relatively simple routines. Occasionally the scheduling or inventory control decisions may be complex, but this is not typical. Usually these applications are justified on the basis of reducing overhead costs and errors and of accelerating operations or improving service. Also these applications often do not involve important changes in the operations beyond substituting the machines for repetitive, uninteresting manual labor. So long as these applications do not require a revision of business objectives and criteria, top management participation in the decision to install an electronic computer or data system ordinarily is no greater than the decision to install any other piece of equipment of equivalent value.

The first large-scale computer installed in industry for business purposes was the UNIVAC in the Major Appliance Division of the General Electric Company at Louisville, Kentucky (17). The computer was installed to mechanize routine clerical operations, to reduce overhead costs, and to speed the processing of information. It is used for such current operations as payroll and labor distribution, material scheduling and inventory control, order service and billing, some general and cost accounting, and in certain cost of distribution and cost of sales entries. In addition, sales and inventory reports are prepared. A few "planning" applications have been added.

Another early installation of an electronic data handling device was the American Airlines—Teleregister "Reservisor." The primary purpose in the reservisor, of course, is to accelerate handling reservations on the airlines numerous flights, as they are received from numerous offices, and to reduce handling costs.

The National Cash Register Company has developed a system especially for department store sales and inventory data processing. The system transmits a record of each sale identified by item, price, and names of sales clerk and of the purchaser from the cash register to a central computer via a punched paper tape. This makes it possible to keep a continuously current record and analysis of inventories, accounting for receipts and sales. It also permits analysis of a store's position and activities by department, sales person, stock item number, or other appropriate management control variable. This provides management with a new level of control over operating variables. A similar kind of application is being studied jointly by the Associated Merchandising Corporation with RCA, using the RCA Bizmac.

The Texas Company uses a large scale computer to handle mathematically the flow and material balance in some of its refinery operations. This permits closer control of and significant increases in the refinery operating efficiency. With continuous large scale computations the process control technicians can achieve better balances in the refining processes, leading to more profitable decisions on the grades and amounts of crude oil entered into the process and on the composition of the finished products to be produced. These decisions are aided by the computer and implemented through the regular processing control.

Monsanto Chemical handles such current operations

on its IBM 702 as general accounting, financial reports, departmental expense analyses, production cost analyses, sales analyses cost of sales and gross profit by products. It is adding to this raw materials and finished goods records, payroll, and later, budgetary planning and control.

The Bank of America plans to install and use a special-purpose data handling device, the Electronic Recording and Machine Accounting system, familiarly known as the ERMA. It was developed by the Stanford Research Institute and is being manufactured and distributed by the General Electric Company. It is a device for handling the daily transactions in banks to obtain continuous balances of the customers' accounts, the bank's position, and summaries of operations. The Sylvania Electric Company has developed a data processing center in Camelia, New York, serving as the center for a large information and control network throughout its company. It links Sylvania's manufacturing plants, its sales offices, and its warehouses. Plans are to analyze production, sales, and inventory information for management control purposes. It also will handle payroll and labor distribution. In the insurance field, several large companies have installed large scale computers for handling their premium billing, their accounting, and their payroll and related processes. Similar installations have been made in the public utility and rail transportation fields.

These early current operations installations already have had a profound effect upon computer and data processing developments. For example, it has been the experience in many of these installations that on-the-line operation with good random access is far more important than general-purpose high-speed computation. The John Plain inventory control computer and the subsequent developments from it at Remington Rand, including the UNIVAC file computer and the IBM RAMAC are examples. These are large departures from the early trend of developing larger and larger general purpose computers. They indicate a trend toward computers and components which will handle the unique requirements of the activities in the current operations network. In one instance a large aircraft company changed its plans, dropped a large-scale computer and ordered several "on-the-line" UNIVAC File Computers for its inventory control, scheduling and dispatching activities. Although it already had a large-scale computer, one early company found that its purchasing department and materials control personnel need to be able to interrogate the computer from their desks, at random times, and with rapid access. The arithmetic of their inventory accounting is very simple. These needs were not satisfied by their large-scale computer.

At the same time, some variation has been found in the usefulness of large-scale computers for scheduling current operations when the computations for decision are complex. On the one hand, Alan S. Manne of the RAND Corporation found in a study of the U. S. Military Air Transport Service that computer scheduling of aircraft through linear programming methods did not appear to be practical. "It would require immediate access at unpredictable times to an expensive electronic computing machine, whereas the gains being only in the order of 2–3% in terms of the potential increase in useful airlift from the existing resources." Similarly, I found in one typical shop loading instance that in order to do as well as the foreman I should require upwards of ten hours of computing time at unpredictable times in order to do what the foreman could do with ten to fifteen minutes "back of an envelope" estimating. Obviously, this led me to using a different approach not requiring a computer and giving more reliable results. These are examples of the complexity of computation which often is found when intuitive decisions are attempted by mathematical methods. On the other hand, George Feeney, Stanford Research Institute, studied the empty freight car distribution on the Southern Pacific Lines (6). He found that significant savings could be achieved in routing empty cars from areas of surplus to areas of shortages if a *weekly*-distribution problem were solved by linear programming methods on a large-scale computer. He observes "clearly the machine is just as essential to the data reduction stage. Even though all the basic information was already available in existing reports, there would have been no practical way to process such a huge quantity of data with the speed and accuracy required without a computer. Thus even though this problem was 'solved' through operations research, the solution would have been of no practical value without a computer to provide the basic system information and carry out the necessary numerical analysis." Although each of these three problems results in a similar mathematical problem, formal linear programming solution on a large-scale computer was economic only in the one instance where the computations could be made regularly (weekly), and where the computations are not so large that they are uneconomic to perform. Other situations which were feasible include some of those described by Henderson and Schlaifer (9): for example, the H. J. Heinz Company's ketchup allocation and transportation problem, the make-or-buy problem, the "where to sell and produce" problem. Some of these are especially suited to routine solution on a large-scale computer. The Charnes, Cooper, and Mellon study in refinery programming spearheaded the use of linear programming on large-scale computers for scheduling and controlling current operations in large continuous process systems, such as in the Texaco example (3).

Whether a computer is applicable in any of these scheduling instances is, of course, a question in economics. Is the value of the computer solution over solutions by other means greater than the additional cost? Can it be performed within the time required? However, an important part of the question is whether suitable computational methods can be developed for any problem. For example, it is understood one large company is experimenting with a priority index number system for scheduling in a job-

lot manufacturing plant. It is estimated the method will reschedule a large shop (several thousand lots on several hundred machines) in approximately 15 minutes. The method has not been published as yet, but is similar to an earlier method (20). It avoids the need to invert a large-scale matrix, which is always time consuming.

SALES FORECASTING

In short range Sales Forecasting there are many techniques that can be applied routinely to sales data in order to obtain forecasts of near future sales. While these do not remove uncertainty from the forecast, they do give more information on which to base decisions. In one firm in the consumer goods business a regular computer procedure was developed and used for weekly sales analyses. It performed the following operations:

(a) Prepares the sales report from raw data, seasonally adjusted the report, and then compares current sales with sales budget and with last year's sales.

(b) Prepares a best fit for the sales trend, for the preceding three months to date and compares with the trend from the preceding period in order to note any change. The sales for the next two quarters are computed using the most recent trend.

(c) The standard error about the trend is computed, and used to estimate the upper and lower limits of the range within which forecasted sales are likely to occur 95% of the time.

(d) With existing production rates, the inventory levels are computed biweekly to show the amount of inventory on hand for the next two quarters if sales should be as projected by the current trend or as projected by the upper or lower limits.

These computations are performed as part of the regular procedure for analyzing sales returns. The results are included in the weekly reports to operating managers. Preparation time for all of the above is less than for preparing only the basic, unadjusted current sales report by manual methods. A separate and more elaborate procedure is used for longer term forecasts. However, most of the data developed in the routine analysis can be used in the long term studies. A regular monthly multiple correlation study is made against critical indices from the FRB and Bureau of Census Studies. This permits frequent and early detection of changes in consumer buying habits, product preferences, and the impact of economic and social changes upon future sales, etc. The computer inverts a 38×38 matrix, i.e., solves a system of 38 simultaneous equations in 38 unknowns in order to obtain these data. A matrix of this size can be inverted in a matter of minutes by a modern large-scale computer. Manually it is virtually impossible. Of course, the computer companies and Service Bureaus have "canned" routines for most any required mathematical or statistical operation.

Dr. W. L. Murdock provides an excellent example of the applicability of operations research in design of the organization and automation of production control as part of the current operations network (16). In a study at an industrial products manufacturer, a new system was designed which reduced overall factory cycle time for one product line from six weeks to less than two weeks. It involved formulating the structure and flow of information in production control in rigorous terms: the purpose of each decision and the extent of logical choice, the minimum information needed to represent the matrix multiplications (production parts list explosions, shop loading, cost distribution), the volume of elementary operations (addition, subtraction, multiplication, division), and the value of these operations to the information and decisions they support. With this preparation, it was possible to design an optimal information system for production control; the design then was translated into hardware, such as counters, selectors, comparing units, etc. An important discovery in his study was that for this current operations network, the IBM 407 punched card machine (or its equivalent) was better suited for the purpose than any other 1957 mechanical or electronic computer. The reason is that by using Boolean algebra or logic it was possible to increase the information capacity of the card in this instance by several thousand percent. Thus, a better balance was obtained between input-output rates, calculating rates, and the rate at which information was needed and could be assimilated by the operating personnel. This balance would change, however, if the computations were more complex and required a general purpose computer, or one with a stored program.

Many of the preceding examples illustrate the large amount of interconnectedness among the various activities in the current operations network. Particularly interesting is that if one activity is mechanized, it often is mutually helpful to mechanize the many others which relate to it. For example, if payroll is to be handled by an electronic data system it is very helpful if preparation of job tickets be similarly handled. Also, it becomes helpful if production order writing, production control, inventory control, labor distribution, et al., follow in turn.

APPLICATIONS IN BUSINESS PLANNING

The process of planning the future of a business is becoming increasingly complex and important. Technological change is more rapid and severe. Automation tends to increase the investment and often to reduce the flexibility of plant and equipment; at the same time consumer preferences may vary more widely. The structure of the economy is now so interdependent that changes in one segment quickly and importantly impose changes on many other sectors; one business is affected by another's decisions and actions. The concept that the future can be planned, however, is becoming increasingly recognized (18)(19). In a recent survey, the personal improvement listed as second most sought by the members of the Young Presidents Organization was in "planning" (21). And, most of the problems reported in that survey are included in "business planning" rather than current operations. Thus it is clear that "business planning" is important. If the computers can be applied usefully in the activities thereof they should offer important new opportunities. Some of the applications are illustrated below.

ECONOMIC ANALYSIS AND FORECASTING

Through the use of various econometric models, such as the Leontief Input-Output model, or certain of the structural or growth models of economics, an industry or a company can compute (and some do), according to a mathematical model, the probable timing and magnitude of change in its industry due to expected changes in other sectors of the economy. For example, suppose a company in the specialty metals business wished to estimate the magnitude of the effect upon its industry from the opening of the St. Lawrence Seaway. It sells to manufacturers of rolling stock, to manufacturers who sell equipment to the manufacturers of rolling stock, to those who supply products to these manufacturers, etc. The change in the company's industry would not be proportional simply to the expected reduction in freight car usage. Rather it would include changes due to interaction of the primary industry being studied, the railroad industry, on many other successive industries and their activity levels. This kind of situation results in "simultaneous" interaction of many variables, and in solving a large system of simultaneous equations. Again this often requires a large-scale computer.

This technique has been developed to a high degree by the Defense Department to determine the full impact of a proposed peace or war production program on the economy and the capacity of the economy to meet those programs. Indeed, this is reported to be one of the major uses of the U. S. Air Force UNIVAC located in the Pentagon. There are other techniques which give promise of being useful in predicting economic and business activity, and which usually require a large-scale computer for solution. One of these is the "leading indices" study being made by the National Bureau for Economic Research, under the leadership of Dr. Millard Hastay (8) and Geoffrey Moore (15).

BUDGETING

A company's budget represents an excellent instrument, or "model," through which to study the aggregate effect of various business and function policies and plans, such as marketing, manufacturing, and engineering. A properly designed method of budgeting can lead economically to an "optimal" program—that is, one which is best from among the many alternatives and considering the interactions of the various elements of the business, one on the others. If the budget "mathematical model" is so designed, it can include effect of product mix, uncertainties in sales and production, and nonlinearities in the price-volume and cost-volume relationships. It can cover several time periods and, hence, can optimize in relation to:

(a) Dynamic costs, such as those involved in accelerating and decelerating production to accommodate to possible alternative strategies in production leveling.

(b) Time phasing and variations in magnitude of costs and revenues due to budgetary allocation strategies which top management might follow (that is, timing and magnitude of alternative programs in advertising, research, production, sales promotion, etc.).

(c) Cash and other asset flows for the various alternative strategies.

If a probability model is used, it is possible to compute "expected" or most likely outcomes if there are no basic changes in the industry, as well as the range of likely outcomes and the probability thereof. For example, it is possible to compute and include in the budgeting decision, the probability that a specified, initial amount of cash would be absorbed in the various assets before those assets are liquidated, such that cash would be temporarily a restriction on business plans and operations. This permits planning and optimizing cash utilization in the same manner that utilization of inventories are planned and optimized.

Optimal Solution of such problems as make-or-buy, product mix, what to produce, etc., can be the basis for an optimal budgeting procedure—if the time span of these problems is extended to cover the budget period. Thus, the solution of the generalized budget problem specifies levels of the various activities, the resources (including cash) required, the product mix, the levels of employment, etc., which are best for the period. The advantage of this method is that for any set of assumptions about future business it computes only the one best or a small number of equally good programs or budgets from which management need choose. Hence, the process of decision making and program planning for the budget is based on the same assumptions as those for functional planning and decision making. If integrated, all can be greatly improved and accelerated. This simplifying procedure, however, is not always followed. In one company with a large computer, the budget department developed a procedure for rapidly generating a very large number of budgets, say 3,000, each for a representative product mix and volume, and presenting a full summary budget for each. Then, the top manager was expected to choose from among these 3,000 possibilities, the one he wished to follow. This method is an example of the hidden hazard of producing too many reports, because it is so easy to do so. Aside from the excessive volume, it is defective in that it does not bring the top managers' assumptions into clear perspective so they can be examined, tested, and used by all those doing any phase of business planning. In addition it does not economize top manager time by performing optimizing calculations for him.

Professor Clay Sprowls, University of California, Los Angeles, using the Bureau of Standards SWAC computer, has developed procedures and basic data for probability budgeting. In this approach it is possible to compute the "expected" or most likely range of outcomes from a program and budget. It is possible to compute and include in the budget decision, the probability that a specified, initial amount of cash would be absorbed in the business' assets before those assets are liquidated. Thus, it com-

putes the probability and magnitude of any cash restriction on the business plans and operations.

The American Management Association recently announced an "operational gaming model" it developed for for top management decision training. This model has just emerged from its experimental wraps, and is an example of how the chief executive can use his budget and computer to practice competing in a simulated game representing his industry. In the AMA game his competitive alternatives or strategies are his policies or choices in his allocation of his company's limited funds between various business activities, such as research and development (product and manufacturing) *vs* advertising *vs* plant expansion *vs* production. It is understood this technique will be in the AMA's recently announced Advanced Management Academy.

The choices or decisions in the AMA game are made by the competing executives for each successive quarterly period. Approximately twenty minutes are required to compute the interactions in the market from the choices made in the preceding period. Thus several years' simulated competition are collapsed into less than a day. An IBM 650 has been used thus far. Of course, if an IBM 704, a UNIVAC II, or a specially designed analog computer were used, the computing time would be less and the model could be more complex and realistic. While the AMA's purpose is for training top management in this critical strategy, its success indicates the practicability of using similar techniques for the budgeting procedures within a company. By constructing a suitable game model of its industry, a top management team could test its policies and strategies and thus more rationally select those which it believes best, considering probability of different levels of profit or loss from different policies and strategies, and the selection of these by competitors. The budgeting model or game for this testing could include the interplay of price, product, investment, and other business strategies.

Although they offer many advantages to be gained by using them, there are certain prerequisites to being able to use such new methods as these for business planning. The top managers must have high concept formation ability; that is, they must be able to imagine effectively and deal with reality in abstract terms. For example, Katz observes that:

> At lower levels of administrative responsibility, the principal need is for technical and human skills. At higher levels, technical skill becomes relatively less important while the need for conceptual skill increases rapidly. At the top level of an organization, conceptual skill becomes the most important skill of all for successful administration. A chief executive may lack technical or human skills and still be effective if he has subordinates who have strong abilities in these directions. But, if his conceptual skill is weak, the success of the whole organization may be jeopardized.

Top managers require this skill because they deal with the world largely indirectly or "abstractly," that is, through others or through symbols. Operating managers do not because they deal with concrete reality. Goldstein (7) has observed that "people are differentially set to handle the events they encounter, some seeking constantly to form conceptual groupings, others to deal with events concretely in terms of simple identity categories. That is 'this thing in all its unique appearances' as compared to 'this thing as a member of the class of things alpha'."

Bruner (2) et al. point out that the "thematic approach with its essentially concrete method of dealing with reality is efficient in dealing with familiar situations. However, the abstract is more efficient in interpreting and dealing with new unfamiliar situations." The top managers bear the broad responsibility for interpreting the new and unfamiliar and for integrating into the objectives and criteria of any business. The computer, through such techniques as the budgeting or gaming model, enhances the speed and extent to which top managers can devise and test business policies, programs, and budgets. While these methods depend upon top management facility in concept formation, they also are an important aid and extension to that ability. Thus, they will tend to enhance the advantage which such top managers already have.

PLANT LOCATION

The optimum location of one or a set of plants, warehouses or stores is another problem that has been handled effectively on a large-scale computer. The factors affecting their profitability and serviceability are numerous and complexly related. There usually are two phases to such problems. First it is necessary to determine what factors are relevant, e.g., proximity to other shopping centers, cost of rent, proximity to labor. Once the effect of each of these upon profit or service is known, the second step can be taken: to compute via a mathematical model the best location.

In both these steps the mathematical problem often is so large that computer solution is necessary. One of the more publicized location studies was that conducted by the Research Division of Rayco, automobile seat cover and top manufacturer. In its study, it discovered for top management what factors most affected its sales and then helped to pick the best locations. Many other similar studies have been made, of course, by businesses in manufacturing, distribution, and retailing. One of the more recent location studies was described by H. P. Berry for the Maxwell House Division of General Foods Corporation (1). He described how the transportation of model (11) was used to assist in planning the location, timing, and number of additional production units which will be required by Maxwell House over the next decade.

PERSONNEL PLANNING

Personnel selection and recruitment can be aided by large-scale computation. One of the problems confronting personnel researchers is to determine the extent to which certain individual measurable characteristics or

combinations of characteristics affect and predict job success. The number of factors is large, as is the number of subjects which may be studied in any experiment. Thus, a large-scale computer is an invaluable aid in computing the effect of each factor. And, like the location problem, the computer may be useful in solving the "assignment Problem" (23) for assigning a given set of men to jobs so that the best overall placement is obtained. Of course, as in the MATS and the Southern Pacific Company cases, a solution usually is worthwhile only if its value is greater than its cost.

LAYOUT PLANNING

The optimum layout of a store, warehouse, or plant is another problem, on which computer solution often is necessary. Many factors interact in determining the best layout, such as the machine sequences of materials, the size and location of storage areas, the amount and kind of equipment, the length and balance of assembly lines, product mix and volume. In several companies, this problem has been formulated in a manner very similar to a problem presented by Henderson and Schlaifer for the SKF Company Study (9). In that latter study the objective was to select which processes to use and which products to make with a given plant layout and equipment. The reciprocal problem is: what plant layout and equipment are best for a given product and process structure. The SKF Study yielded $100,000 savings per year: the savings both in cost of layout and in subsequent operations has been reported to be even greater when the original layout is computed in an optimal manner first. This approach avoids "building in" inefficiencies, such as bottlenecks, backtrack flows, congested areas, inadequate allowance for variations in load, etc.

INVENTORY PLANNING

Often inventory and equipment policies can be established more effectively through the use of a large-scale computer. In many ways the control of material inventories is similar to the control of dollar inventories discussed under budgeting. Similar techniques are applicable. A recent study of this type was reported by K. C. Lucas of the Thompson Products Company (13). The computer was used to simulate behavior of incoming orders and to test the result of different inventory policies on customer service and deliveries. This helped top management decide between amount to invest in inventories and the level of service and deliveries. The computer was not used, in this case, for controlling current inventories, but rather in planning inventory policies and assuring they would be consistent with other business policies. The computer made it possible to obtain simulated experience to test the policy before it was implemented. A similar kind of problem and solution arises in determining the optimum capacity of a facility, such as a toll gate, a machine shop, an airport or other. This is often called "queueing theory." The outstanding current study in this was made by Leslie Edie of the New York Port Authority (4). It is understood that this study resulted in substantial savings. Similar computer simulation studies were made of air traffic congestion at La Guardia Airport in order to determine maximum traffic schedules. With the computer it was possible to simulate the actual arrival of aircraft under different schedules to determine the probability of "stacking up" or of experiencing delays in landing of different lengths of time. The administrators then could decide what level of risk of stacking they wished to accept and hence could determine the maximum allowable scheduled usage of the airport. An interesting result of this and other studies is that as the average arrival rate of randomly arriving aircraft approaches the rate at which aircraft can be landed, average delay tends to become large and to approach infinity. Thus, it was learned actual capacity with safety allowance is much less than theoretical capacity.

Many industrial companies have begun to use this method for determining the optimum amount of capacity of their plant and amount of equipment to provide that capacity. A further complication often arises in these instances because level of service and delivery is related to both plant capacity and inventory levels. Thus, an optimal solution is even more difficult and has required extensive computer time to simulate and to select an optimum in both regards. Magee has described further examples of inventory problems, among which some require a large-scale computer for solution, while others do not (14).

APPLICATIONS IN THE LEARNING NETWORK

The Rayco, the Sales Forecasting, and the personnel evaluation examples illustrated the use of computers in the learning process, as well as in planning or operations. There are other examples which illustrate their use primarily in routine learning. In general, the computer is valuable in these uses because of its ability to perform mathematical operations which unravel complex interrelationships, and thus brings them within management understanding and control.

Cost accounting as a branch of applied statistics is concerned largely with analyzing variations in operating results into their many causes, and thus learning how better to operate in the future. For example, cost accountants seek to analyze an actual cost into its components and the causes of its departure from a norm for each component such as labor cost or efficiency, material cost, supervision, or other. The results of the analysis indicate whether any phase of an operation is or is not in control by the relative value of the variables. If there is a departure from norm, explanation is usually sought. In a way, this corresponds to the multivariate analysis of statistics.

Some of the more advanced accountants have recognized this and have begun to make use of appropriate statistical theory. The following is one of the steps they have been able to take, helped in large part by a large-

scale computer. The allocation of overhead expenses among several departments when some of the departments provide each other with services results in a problem in simultaneous equations which accountants have solved only by an approximate method. An exact method is to solve the system simultaneously. At least one large firm now has a mathematical routine incorporated in its accounting procedures for this purpose. This permits exact allocation of these costs and more reliable information for management control.

A more important problem in cost analysis is for direct and indirect factory and marketing operations. In this area, also, computers and statisticians have much to offer accounting. The point to be made here is illustrated nicely by a personal example. Certain studies were made which increased productivity in a large operation and reduced labor requirements even though output was increased. One consequence was, however, that an increase was necessary in the indirect labor serving this operation. Direct labor was reduced, say by 20 persons, or 33%, while indirect labor was increased by 5 persons, or 50%. Because of the reduced direct labor base, indirect as a percent of direct was even more greatly increased from 17% to almost 40%. The result of saving, say $50,000 per year was, in certain accounting reports, to increase overhead, and hence make everyone, including the foreman, look bad. The saving is soon forgotten, but the overhead lingers on.

The beginning of a solution to this dilemma is suggested, not by a statistician, but by an accountant, Dr. W. J. Vatter, of the University of Chicago (22). So far as I know, no company has followed his lead to its logical conclusion. Any company with a large-scale computer and competent statisticians in its accounting department would be in a position to do so. The suggestion is to treat a business, for cost analysis purposes, as an experiment. When this concept is pursued to its logical conclusion, the result would be to give managers a wholly new set of data for managerial planning and control purposes. That is, in the business-as-an-experiment approach, the concern is with the effect of one level of activity on the efficiency of other activities affected by it, either directly or indirectly. Take a simplified example of a factory operation and a tool room to service that operation. Usual cost accounting procedures computes total cost, cost per unit, factory cost, and tool room cost, as well as departures from a standard. Such limited analysis fails to pick up the relationship between size of tool room work force and efficiency of the factory operation. The business-as-an-experiment approach, if followed, would pick up this additional information. That is, it would pick up the *rate* at which the efficiency of factory operations is increased or decreased as the size of the tool room operation is increased or decreased. Then, with regular cost information on the two operations, it is possible to balance marginal costs (or revenues) so as to achieve the lowest cost (or highest profit) operation. If it is extended to all the departments of a business, and if cost data are available for each department, then, the cost accounting data becomes a basis for optimizing the level of activity in each of the many departments.

There is new information added by this approach. The present cost accounting data show only a point on a cost line, but not the slope or best direction to go on that line. Thus a manager only can guess from cost reports whether an operation is in best balance. With the addition of the slopes (and marginal costs), he can know, for example, that an overhead rate of say, 160% is too low (or too high) and that it should be increased (or decreased) as well as the total value of doing so.

In one multi-divisional company, one division vice president uses the traditional kind of cost data as a primary tool for comparing the operating businesses within his division. For example, one business may show tool room as 20% of direct labor and materials handling as 30%, whereas in another business the figures are reversed. Then, he needles the general manager of each business to reduce overhead in his higher item to the level of the other general managers. The fallacy in the approach is that it is not necessarily most profitable for each business to have both tool room and materials handling at 20% of direct labor. However, neither the vice president, the two general managers, nor their accountants can prove or disprove it—using present cost accounting methods. If the correlation coefficients and marginal costs were determined, then it would be clear to all whether any one or more activity should be increased or decreased. The current trend toward greater fixed and overhead costs and lower direct labor costs that are associated with automation makes the business-as-an-experiment approach even more important in getting meaningful and useful information for managers. Before the advent of large-scale computers, it was not feasible to handle the large computation load which computing partial correlation coefficients for a large system implies. However, the opportunity now exists for accountants to do so and thereby to increase the value of their reports to managers. Of course, this step will require closer integration of cost accounting, Industrial Engineering, and data processing. From a psychological and common sense point-of-view this approach should be satisfying. That is, present accounting reports to managers simply exhibit overhead rates and any increase, say, to 160%. This may look like a large figure whose relative size alone is sufficient to suggest it ought to be reduced. But, there is no clue in the report as to whether it is indeed too high or too low. In the alternative suggested here, the marginal costs or productivity of each activity would be shown. When all would be zero, the optimum would be achieved. The larger any marginal cost figure reported for any activity, the greater the profitability of correcting it back to zero by increasing or decreasing the level of the activity.

Appendix A, "The Tale of a Cow" is a story which illustrates the above point more poignantly. Chapter I was circulated within a company by the accounting depart-

ment in an effort to induce reductions in overhead costs. I added Chapter II for a friend to help him in his effort to illustrate to his top managers more clearly the idea that, especially in this age of science and technology, high overhead rates can be more profitable than low rates.

Similar kinds of opportunities could be given for other instances in business learning, including, for example, in long range sales forecasting, in market and customer analysis, in quality control and analysis, etc. However, it deserves a note of explanation that in order to use the methods suggested here it is necessary to develop suitable models or "theories" of the business or operation being studied. Although there is no doubt of their value in managing a company, there also is little doubt that building the model or theory requires much skill, insight, and conceptual ability. It is not something for which the computer manufacturer would have a canned routine.

EFFECT OF A COMPUTER ON A BUSINESS

The possible effect which a computer will have on a business should be understood and appreciated, if at all possible, in advance. The managers then can incorporate the computer and computer program smoothly and to its full range of their application. Two examples below illustrate how this was done in two businesses. Although the beginning in each case was different, the results in adapting the computer to the business and the business to the computer were essentially the same.

An innovation as fundamental and as pervasive as electronic computers does not occur often. Hence, in order to illustrate the possible effects of a computer on a company and to put innovation in perspective, consider a similar kind of problem of incorporating innovation. Suppose you were the aircraft designer who had just designed the JN4 Jenny. Suppose another engineer announced he had perfected the jet engine. Would you put a jet in a Jenny? If you were to do so, what are the different ways in which you could proceed to design a jet engine into that venerable old craft. What would be the probable effects of each different way? What kinds of problems would you have to solve in each case? Let's think briefly about this situation.

If you were to put a jet engine in a JN4, here are some of the consequences. You would have much greater thrust and much greater speed, even with all other factors unchanged. But, the additional speed would call for a change from fabric to metallic surfaces on the wings and fuselage. The additional weight of the metal skin would give a heavier craft with the need for stronger spars. The higher speeds and weights would place a greater load against the control surfaces, and would require a different control system. The different geometry of the engine would require a differently shaped and designed fuselage. Obviously, one could enumerate such changes almost indefinitely, even to the new shoe strings for the pilot's anti-blackout uniform. Thus, while you may begin with a Jenny, you would not really put a Jet in a Jenny. When you finished making the changes in design to adapt to the jet, you would have a wholly new aircraft.

What are the different ways in which to redesign the JN4 for a jet? There are at least two: first, the craft could be redesigned in a series of single steps, correcting at each step one defect or difficulty as it is detected. That is, the designer first could add the metal surfaces, then the stronger wing spars to compensate, then more powerful control system, etc. Let us call this redesign process "adding on." On the other hand, there is the "systems approach" method. The designer could initiate the redesign of the aircraft simultaneously for the whole as an integrated system, considering the new major components which could be included, their interaction, and the limits and load they place on each other. This would continue until a rational synthesis is obtained. The "adding on" method usually leads to just that: adding on bits and pieces. The "systems approach" which looks at total purpose leads to a fresh functionally designed system. The adding on process probably would have led to a slick aluminum biplane with good performance as the outgrowth of the jet in the Jenny. The systems approach probably would have led to the current swept wing, high performance monoplane.

Of course, in business we seldom follow the "adding on" process, except in most everything we do. For example, in budgeting, it usually is the practice to study carefully only the "additions" over last years' budget. We seldom re-examine the whole in a new analysis of work to be done in order to achieve a new functional design. In data processing, the "adding on" method also is used: the system may begin with manual methods, then later tabulating machines, eventually a large-scale computer or electronic system. It is understood how this can happen: it is easy. But it is not necessarily "best," since it does not lead reliably to the most efficient, functional system.

Last Fall I began a talk with the following paragraph:

> In the literature on electronic computers, there are numerous titles on specialized applications of computers, such as "Application of an Electronic Computer to Payroll," "Inventory Control on a Large-Scale Computer," etc.

While these are excellent papers by very competent men, they usually are the result of "adding on." Of course, no one is more aware of the deficiency of this method than the man whose top managers will not let him take the "systems approach" to designing in the computer. While I do not imply that a large-scale computer and/or electronic data handling system is a must for every business organization, I do assert that when one is installed, it should be examined from the "systems approach" basis, rather than only the "adding on." A prime example in this regard was given by Professor Howard Aiken at the 1955 Annual Conference of the Operations Research Society of America. In a paper on a data processing study for the Edison Electric Institute, he reported that:

> 1. By installing an electronic data system, it was possible to show a savings over the manual method.

2. By removing the electronic system, it was possible to show a saving in readopting the manual method.

The answer to the dilemma lies in the fact that when the computer system was installed, new methods were developed for the operation. But, the new methods were so much simplified that a computer was unnecessary and it was cheaper then to perform the operations manually.

Two examples from business are presented which illustrate in more detail how a computer or data processing system can be designed into a business organization on the systems approach basis. In one case, the computer application was initiated in engineering, but the chain reaction led through the business to a new design. In the other case, a data processing study was merely incidental to a re-examination of the nature of the business by the General Manager and his immediate functional managers; although these are examples of computer applications, they also are examples of a more general problem: incorporating innovations into a business. As such they illustrate the deep understanding of the assumptions and nature of a business which is necessary in order to design and manage it effectively and to incorporate fundamental change into it. This process I call "managing progress."

EXAMPLE ONE—A SMALL ORDER PROBLEM AND A DATA PROCESSING PROJECT

This is an example of a business in which in the ordinary course of events the top managers restudied several major business problems, including business and product scopes. The need arose from technological and market innovations. Two apparently independent problems were studied, at first independently of each other. The interaction and interdependence between the two studies were emphasized and analyzed through reference to each one's effect upon the business as a whole or as a complex system. One problem was due to an excessively large number of small orders for the product, these small orders appeared to be unprofitable to handle through sales and inventory. The other problem was a task force study of the desirability and feasibility of developing and installing an electronic, integrated data system around a medium-scale computer. The example illustrates how the changes in the design of the organization as implied by one study affected also the other study and its implied changes in the design of the data system. Thus, some problems in inventory and sales policies as well as business scope are analyzed first and then they are shown to be important determinants of design of the data handling system.

For the "small order problem," an independent firm of consultants recognized expert in scientific methods in inventory control was retained by the general manager of the business to help develop an appropriate set of decision criteria for guiding the sales and inventory personnel in accepting or not accepting any incoming order. The consultants made a thorough study of the situation and determined the breakeven point on orders for different products. They made careful operational studies of the order handling procedures and the packaging problem in relation to the various sizes of orders. They devised methods of illustrating the effect of various policies or decision criteria on how much it costs to provide service to customers who do not order large quantities. Thus, the consultants made it easy for management to decide how much it needed to spend to achieve any given level of customer service in these regards. The result of their study was a report to the general manager in which were presented the facts of the situation so that the general manager conveniently could make a decision, in his seasoned judgment, as to how far he was willing to sacrifice service to customers as a means of eliminating smaller orders. With this decision from the general manager, the consultants then could devise a set of specific decision criteria embodying his valuations, which criteria could be applied by sales, and/or inventory clerks to each incoming order in order to determine whether it should be accepted or not.

Before authorizing the application and utilization of this decision rule, the general manager reviewed with others in his company, the work the consultants had performed and the probable effect of the proposed decision criteria upon the operation of the business and its other parts. This general area had not been assigned to the consultants. Some of the participants in the review had been trained in the systems synthesis approach to the design of business organizations presented here. In the discussions which ensued the general manager and the others brought out many facts on how the order size decision criteria would relate to other parts of the business. For example, some customers purchase small quantities on first orders, but then standardize on the product for large quantities after the design and construction have proven satisfactory. Obviously, the cost of not serving these small orders is more than just the foregone (albeit negative) profit on the order, but includes, also the profit on lost future business. Hence, other criteria than size alone are relevant to the decision to accept or reject an order and, therefore ought to be included in the decision criteria.

The possible effects of not accepting orders below a given size upon sales and distribution were explored. Would it mean a larger demand upon the dealer and distributor pipeline and inventories and could they handle it? Would it divert significant amounts of business to competitors? Would it cause loss of large orders from customers who also placed small orders? What communication system would be necessary in order to maintain the same degree of control over sales, inventories, and schedules if the small orders were received via dealers and distributors? That is, interposing the distributors and dealers between the factory and the customers for these orders would alter the character of the demand placed upon the factory; it would increase the average order size

and decrease the average number of orders. Thus the factory inventory level and the criteria for establishing inventory levels and for determining sales trends would have to be revised. These changes, in turn, would affect the production order sizes to the factory, possibly affecting the shop scheduling and loading procedures and rules, as well as the related information and decision networks within the shop. It might affect also the layout and organization of the shop, whether job-lot or serialized production.

The question then was raised whether it might be preferable to remove the items involved in small orders entirely from finished inventory and to establish separate geographically dispersed small shops to manufacture them on a "to-order" basis until their volume increased. If this were done, it would be possible to improve the character of the main production shop by removing some of the shorter run items, and thus permitting fewer, longer runs with greater economy in the shop. This would lead also to conditions more suited to higher levels of automation in the shop. Of course, this possibility was dependent upon the feasibility of establishing small shops that would be large and stable enough to keep a minimum crew occupied, but without taking away so much from the main shop that it would decrease the efficiency of the main shop. Thus, it was necessary to study the simulated interaction of the proposed small shops on the main shop so that the resulting combination would be an optimal allocation of work between the two. An advantage of the small low-overhead shops also would be less finished inventory with greater flexibility of service on special orders. In addition, it would be possible to establish such small shops geographically dispersed in various parts of the country to serve local customers better.

When these various changes in the design of the manufacturing part of the business were tested for their consequences on the other parts of the business, particularly upon marketing, it was evident that they would permit important changes in delivery and service. Then, in order to evaluate these, it was necessary to evaluate the customers' real service needs, the abilities of competitors to provide these needs, the costs to the business of providing such service, the short and the long range value to the business of providing various of these services. This led to a reconsideration of what would be the optimum product and service scope, together with the amount of resources, design of business organization, and the expected profit from such scope. In turn this led to the general manager's observation that one of his primary entrepreneurial responsibilities in this situation was to re-examine "in what business or businesses are we and should we be?" There were many answers, ranging on the one limit from a business only to develop, manufacture, and distribute the basic raw materials of the industry to other companies which then would fabricate the finished products to, on the other limit, a business which would encompass all important processes from raw materials development and manufacture to finished products manufacture and distribution. With each different business scope, there would be a different design of the business organization necessary to achieve optimum performance. For example, if the former business scope were selected, it would permit managerial and technical personnel to concentrate on homogeneous operations and functions of a highly technical nature. Then, they would be offering essentially their technical skills as their principal product. At the latter limit, the business would combine the highly technical engineering research and development with the less technical high-intensity merchandising activities involved in competing with small and often "fly-by-night" fabricators. Such combination would result in less opportunity for the managers and other personnel to develop the same degree of facility and comprehension of all the details, intricacies, and complexities of their business.

However, it was clear to the managers that they could not expect to have a business which was entirely homogeneous, since that would mean virtually only one customer and one product. Thus, the question became the extent to which the enterprise can encompass diverse, but related, sub-businesses each oriented toward a separate, but related market, product, process, or other basic organizing criterion. Their entrepreneurial task as managers then was to conceive and design the total business so that each sub-business could operate efficiently, yet provide adequate degrees of specialization. At this point, the managers began to refer to their project as the "nature of the business" study, rather than the "small order problem."

As a by-product of the preceding study of business scope the top managers, one of whom was directing the data processing study, saw clearly that it was not possible to decide upon a data processing subsystem except in relation to a specific design of the business organization and the business scope. For example, the size of the random access memory for inventory control is determined by the relative allocation of catalog items between stocked or custom manufactured and is determined by the business, process, and product scopes. If a product is inventoried, then its status should be maintained current in the memory; if custom manufactured there is no stock status to maintain and, hence, no need to use the memory for this purpose. Similarly, the number and kind of processes from basic raw materials processing to finished products distribution which are included in the business scope would determine, for example, (a) the number of inventory items and the number of digits to identify each, (b) the kind of scheduling situation in the shop and, hence the scheduling methods and computing facilities to handle, (c) the kind of communications within the current operations network which would be needed to handle flow of information from customer order to issuing invoice and paycheck, etc.

Importantly, the result of the managers' focusing on these central assumptions underlying the design of the business organization in this manner is to lead to a much

clearer theory of the business and an easier business for the managers and technical personnel to operate. For example, in designing the decision criteria for the sales or inventory clerks, the assumptions, objectives and criteria of the top managers are clearly defined so that the decision criteria can be developed which achieve the common purposes of the business in some optimum way and without conflicting with the other decisions and actions. In designing the data system, the assumptions and objectives of the top managers now can be made clear, so that it is possible to find a test for almost any computer systems design decision. Specifically, even the frequency of reference to a file becomes not a question in judgment for the technician, but a question to which he can have recourse to explicit business objectives and criteria. Thus he can determine a best equipment selection, he can design one step in the program or procedures, or he rationally can synthesize the design of the whole data handling system, but now always in relation to explicit criteria which would assure that the resultant system achieves desired objectives. The most important result of system studies of this type is not necessarily the data processing system itself, but rather the design of an information and decision system within the business which will permit each participant—manager or other—to have the information in the time and form he requires in order to operate and make decisions in a manner which is best from the point of view of the business.

EXAMPLE TWO—A PRODUCER OF A LARGE COMPLEX PRODUCT

In an enterprise engaged in the design, manufacture and marketing of a large complex product, a change was introduced into one part of the business which had extensive ramifications through the whole. In this instance, the product designers planned to use a new large-scale electronic computer for certain design analyses and computations, utilizing the latest in electronic computers. One of the designers, and then the general manager, perceived the very large potential opportunity for using the computer for this purpose and other related business purposes. They also saw the large changes in the design of the business which would be required in order to do so. The following is a brief description of the extent of these changes and of their import to the design and operation of the business.

In the past it had been the practice to perform the design function for which the new computer was intended by extensive "cut and try" methods, with each engineer using his own "cook book" of design procedures and criteria. The result was that given the same operating criteria from a customer, each different engineer would design an essentially different product—different in appearance, construction, and cost, but providing the same operating characteristics. However, in order to use the new facility, it was necessary to change this practice and to substitute for it a single "best" or commonly acceptable design procedure. This basic change led, in turn, to many other opportunities which could be pursued only if the assumptions and nature of the business were restudied and clearly understood so that an effective business design could be achieved. On re-examination, it was clear that the new product design method would permit producing a product which could be made of standard components and/or components with standardized generic shapes and configurations. But, the feasibility of this change was predicated on the technical and economic feasibility of products of this new design as they operated in the customers' systems. This had to be determined by such factors as (a) the relative efficiency of the redesigned product, (b) the extent to which lower costs in manufacture could be achieved through more standardized methods, tools, and inventories, and thus permit lower prices, (c) the potential reduction in cost and price due to more efficient methods of drafting the plans for the product, (d) the extent to which new pricing and competitive policies would be permitted or required by the new product in the market interplay, and even (e) the esthetic acceptability of this product with a "family" design and appearance.

These changes would dictate changes in the basic philosophy and policies of advertising and sales promotion, in engineering and engineering practices and policies. For example, the organization of the Engineering Department was changed. Formerly it had been partitioned into sections according to the size of the product to be designed. Now it was partitioned into sections according to whether the product to be designed is standard or non-standard. In manufacturing, the changes which could be accomplished included new tooling policies and designs which would permit more economic use of tooling and materials with the standardized sizes and shapes of the end items, more economical ordering policies so that materials ordered in bulk would be of such size that it would permit cutting with minimum waste, etc. Even the layout of the factory was reopened in order to achieve the maximum economy in flow and handling that the new design permitted. Advertising and sales promotion were adapted to emphasize speed of delivery, lower price, greater flexibility, and uniformly high quality.

From the preceding it is clear that the introduction of the new computing facility and method into this enterprise resulted in a basic change in the way in which that organization conducts its business in all its parts. This pervasive change was necessitated by the fact that the various parts of the business are interrelated as in a system and no part of the system can be changed except if that change is or can be accommodated by the other components. Thus the original opportunistic innovation as well as the subsequent accommodating changes extended throughout the business. The manner in which the extension took place required a "systems approach" to the analysis of the business. It was not limited to the computer itself.

But, the computer and the "systems approach" provided the immediate stimuli for such re-examination and redesign of the business. As long as the engineers performed the computations manually, there was little immediate advantage to the Engineering Department in using a single standard method. The Engineering Department previously had studied the situation and found there would be no significant saving in engineering man-hours or in product efficiency from adopting a single standard manual method rather than allowing each engineer to use his own tried-and-true method. However, many engineering man-hours could be saved and a better product designed by using the computer for these computations. But, in order to use the computer, it was necessary to develop the single standard computational method. The saving in engineering man-hours and the better product design promised by the computer provided the Engineering Department with the stimulus for achieving the standard computation method. But, this standard method could not be used unless the results of the method, i. e., a standardized product, were acceptable to marketing and manufacturing. Rather than just "adding on," the General Manager then used the occasion as the basis for a "systems approach" to redesign the whole business. Except for the breakthrough provided by the Engineering Department and its computer, this opportunity would not have presented itself so clearly.

It is interesting now to compare the two examples cited above. In the first the managers re-evaluated the scope and design of the business organization according to what business they believed would be most profitable in the long run. This redesign affected importantly the design and desirable operating characteristics of the information and decision network which affected, in turn, the design of the data system. On the other hand, the second example illustrates how a change in the data system forced a change in the design of the information and decision network and which affected, in turn, the design and scope of the business. Thus a change in the design of a business may originate from a direct reconsideration of the optimum design of the business per se, or it may result from a change or redesign in one or more of its components. Whether a change originates with the whole business or with one of its components the result of the fresh approach is the same; all roads using the systems approach tend to the same optimal design and goal. Obviously, in the "adding on" approach, "where you are" determines "where you will go," and that may or may not be the same as where you "should" go.

In the foregoing the "adding on" *vs* the "systems approach" to designing innovation into a business were presented as two distinct alternatives. The purpose in exaggerating the case is to make the point. Of course, all is not black or white; there are shades of gray and there are many compromises in the extent to which one should open a situation to the systems approach. Obviously not all should be so opened; operations must continue—"the show must go on." The systems approach is emphasized because it has been observed in so many cases that the expedient, easy method of "adding on" is used even when it is not appropriate, and that this is one of the primary reasons for failure. There are, of course, occasions when it is appropriate. For example, if a change is made in a component part of a business which increases, say, productivity but does not change significantly the form and timing of the inputs and outputs and it does not lead to other broad innovation opportunities, then the adding on approach is surely appropriate. In any case, the whole business is not the only unit to which the systems approach can be applied. It may be to a branch plant, to a warehouse, or to other appropriate integral components of a business. Most break-throughs in science and engineering are small improvements over existing materials or processes; something as dramatic as a Jet in a Jenny does not happen often. The lulling effect of these small increments often leads to a large accumulation of obsolete methods, policies, or practices. It is in the possibility of this occurrence that lie much of the danger of the adding on approach.

Several concluding generalizations can be drawn from these illustrations. First, it is self-evident that designing a computer or electronic data processing into business on the systems approach basis is a task for top management leadership and participation. The alternative approach "adding on" achieves some useful results, but they seldom are as important. However, it is not at all necessary for the top managers to become computer experts any more than it is necessary for the aircraft designer to become a jet engine expert. What is especially required of top managers is a high conceptual ability, i.e., an ability to "see" and deal abstractly with the possibilities inherent in a change or innovation, to verbalize his interpretations of that change, and to relate it to his policies and objectives. While he may be helped in these by his specialists, the top manager is in possession of the best broad view of the business and of the balance of all its functions, processes, and relations; he has unique responsibility for the whole business. Thus, he is an indispensable participant in any important "systems approach" to redesigning the business. It is recalled from both examples that the General Managers of the businesses did participate personally in the conceptual aspects of the design task and made important conceptual contributions. All of the unsuccessful computer installations I have seen have lacked this participation by top management. I suspect, therefore, that this lack contributes to their failure.

The role of the top manager's conceptual ability in these decisions is made apparent by the fact that one does not make a large commitment in time and money without a clear "picture" of the working results of the project. For example, the General Manager in the second example visualized conceptually the whole spectrum of business activities from engineering to marketing and the way in which they interconnect and interact and he ab-

stractly visualized the effect of various changes upon all of these activities and the future business. This was quite in addition to and beyond the written reports, analyses, and cost estimates prepared by his specialists. It was only when he could "see" all the results mentioned here as part of the future business he visualized that he approved the order to acquire the computer. He did not first obtain the multimillion dollar computer, disrupt engineering practices, and then learn fortuitously that his whole business could be beneficially redesigned. On the opposite side of this coin, the middle managers and specialists importantly can aid the top manager's work of conceptually integrating the many elements of the business. This involves their taking, to their best ability, his business-wide perspective and their analyzing their own plans, decisions, and actions from that perspective.

A second lesson learned from the experience is an understanding of the complexity and difficulty of the technical work of rationally designing a computer into a business organization. While it was not emphasized in the examples, effective prosecution of the studies for the best redesign often involves using many of the more recently developed techniques in mathematics and statistics. For example, at various stages in the analysis and design process, the specialists found important use of the following techniques: concepts of game theory in analyzing strategy on product sizes, on advertising and sales promotion, and on product pricing and model timing; linear programming in factory layout and factory loading procedures; queueing theory in inventory control and purchasing policies, and in data processing equipment selection; Boolean Algebra in determining product classes and interrelations, and in catalog numbering and identification; and logic and the Propositional Calculus in synthesizing and testing the completeness and consistency of the assumptions, theory, and design of the business. All of these and other techniques used in special studies were integrated through systems synthesis techniques quite similar to those used by the electronic engineer. Of course, the other side of this coin is that the business and its inherent characteristics impose constraints on the computer and data processing system. It is not enough simply to design in a computer; rather the selection of large or small, centralized or decentralized, on-the-line or batch processing computer is part of the design problem. Often, it was found, for example, that on-the-line random access for inventory control is more important than general purpose computer flexibility. This led, in these businesses, to distinguishing between the needs for information and decision in the "current operations" *vs* the "business planning" network. For current operations, real-time control, rapid handling, rapid access, and simple computation tend to be the important considerations. For "business planning" general-purpose large-scale computation usually tends to be the prime requisite. Each system, current operations *vs* business planning, thus tends to require a particular kind of equipment. Current operations often require the small, decentralized but interconnected "building block" units, the electronic equivalent of the punched card tabulating equipment. "Business planning" often requires essentially "scientific" computers, usually of the medium to large-scale variety.

In any case, designing a computer into a business is just one special instance of a more general problem, that of incorporating innovations into a business. The changes or innovations which may generate the need or opportunity to redesign a business may originate in any aspect of that business, in its product, in its market, in its raw materials, in its methods of processing and manufacture, in its patent or legal position. Whatever the change, it is not effective until it has been designed into the business according to its broadest implications. The process of implementing any innovation or change in business is essentially the same as that presented here for computers. It is what I term "managing progress." The same techniques, the same kinds of problems, the same need for top management participation is required. Thus, these ideas can be looked upon either as an example of designing electronic computers into a business or as an example of managing progress through designing change or innovation into a business.

ORGANIZING THE COMPUTER

How the computer and related program are organized into a business is important. As is seen in the foregoing examples, a computer and its program may extend across a whole business. One of the principal decision criteria of how it should be organized is, indeed, whether it is to be contained almost wholly within a business function, such as manufacturing, accounting, engineering, or marketing. If it is, then clearly it should be organized as part of that function. If it is to be used in a business process that extends across many functions, then a different organization seems to be indicated. In the more successful business-wide applications the computer and the programming personnel have been located in a separate organization which reports to top manager of the business. This suggests that a business-focused rather than a function-focused approach is helpful in making a business-wide application successful. Possibly the answer is contained in the extent to which the functional personnel can divest themselves of their functional perspectives.

A typical example is given by similar experiences in a large midwest farm implement manufacturing plant and in an aviation product manufacturer. In both cases they found it necessary to have essentially duplicate tabulating and computing centers, one for accounting and one for the sales-inventory-production-purchasing operations. The accountants argued that they must schedule their use of the equipment rigidly in order to meet rigid deadlines, such as payday, month end closing, etc. The other personnel argued that they must schedule their use of the computing equipment rigidly so that operations would be efficient and, therefore, so that the plant could stay

in business and have a payroll and a monthly statement to make. The compromise was duplicate equipment.

Both these computing centers mentioned just above had equipment made by the same manufacturer. This facilitated the extensive communication between the accounting data processing and the operations data processing centers. However, one west coast aircraft manufacturer was not so fortunate. In that instance, the engineering department used square-hole (IBM) tabulating and computing equipment because the engineers believed it was better for their purposes. Accounting and production control each had a data processing system using round-hole (Remington Rand) tabulating and computing system. For many years translators were not available, so that much expense and delay were involved in printing out the long materials lists from engineering, and in punching them for accounting and production control. Professor Kircher reported an experience in which a staff researcher was unable to use a computer because of other demands (10):

> One expert has been working on management science problems at a company which has a large-scale computer. We envied the fact that he had this opportunity. But recently he reported that in a whole year he was given only fifteen minutes on the computer. The rest of the (computer's) time was filled up.

In view of these experiences and the need for the participation of the top manager at the conceptual level, and, on occasion, in reconciling between functional needs for the good of the whole business, there seems to be a case for having any major, across-the-business computer application organized in an afunctional unit reporting to the most junior manager having business-wide responsibility.

Many of the problems cited throughout this article are often called "operations research." Because some of them are solved by computer, many persons assume that there is a direct connection between computers and OR. Actually, most experience has been that a large scale computer is not essential to solving all operations research problems. Certain classes of problems, such as large linear programming or Monte Carlo models, usually require a computer. However, the operations researcher's work is in formulating and solving the problems, rather than in operating the computer. Indeed, for most OR problems requiring a large scale computer a service bureau computer is usually adequate. Thus, to operations research, a computer is simply a means to the end of solving a management problem.

From the other side, OR has a large contribution to a computer program, particularly during the introductory phases. It is at this time that there are large research and design problems to be solved, many of which lend themselves to OR methods. For example, Levinson commented on operations research (12):

> OR should not be sold on its war time contributions. In the war, there was constant introduction of new weapons, and improvements made in their operations through OR sometimes ran to several hundred percent. In industry, a five to eight percent improvement through OR may be high. The reason is that many companies have had long experience with their operations and have made rather good operational decisions. Even so, OR is well worth the money it costs.

Lord Nelson's flagship at Trafalgar was a first class ship-of-the-line, even though she was forty years old. Admiral Halsey's flagship was but a few years old, and contained major items of equipment newly developed during the war. The low rate at which discoveries in science and technology were incorporated into the affairs of the world at that time made the pace of progress quite leisurely. Thus, Nelson's forces had but little use for OR because there was little that these scientific methods could have taught the British Navy about operations of ships in which it had been sailing and fighting for more than forty years. (Although, perhaps with the scientific method of OR they might have increased the rate of innovation, not had 40 year old ships, and been able to make good use of the techniques of OR in designing its current operations.) There was much it could teach Halsey's forces. The important point on which Levinson's logic is incomplete is that he apparently does not recognize that progress has accelerated also for business and industry. For most companies, change is the constancy. Electronic computers are an instance of change. OR can make important contributions to business efficiency and profitability by helping incorporate and design the computer into the business system.

OR studies usually treat business as a system and the OR scientist usually approaches his work from the perspective of the business-wide processes rather than from the functional point of view. Thus, OR usually is organized as an afunctional unit reporting to the most junior manager having responsibility for the whole operation or business being studied or into which the computer is being incorporated. This may be the general manager, the executive vice president, or the president. In one large paper company it is the executive vice president. In a chemical company it is part of the management analysis department which reports to the president. In an aircraft manufacturer it is called business planning and reports to the president.

If the computer is installed and used predominantly in one function and/or if OR is to be done only on operations in one function, say accounting, marketing, or manufacturing, then the same criterion of location holds. It should report to the manager of that function. One large multi-plant manufacturer has OR teams both in the plants and at the company headquarters working respectively on plant and company wide problems. Sylvania has a centralized installation for its current operations data processing.

In some cases, such as E. I. Du Pont, OR and the computing center are part of the same organization. This is because (a) both OR and business-wide computing and data processing are afunctional, (b) both help and are

helped by the manager with business-wide responsibility (c) the personnel in many ways have similar backgrounds or characteristics and (d) some OR problems are solved by the computer. In other cases, OR and the computer are separated. This is especially the case when the computer is primarily for data processing in the current operations network. OR is seldom concerned with day-to-day administration of current operations. When these computations can be highly routinized, they often can be handled best by an electronic computing equivalent of the present tabulating room. In this case, the essential need is access to a manager high enough in the organization to mediate effectively scheduling and equipment selection, and other conflicts between the several functions which may use the computing center.

If there is a large volume of computation in the "business planning" network (as contrasted to current operations), this often is adequate reason for having a separate computer for the planning computations. Usually these computations, whether in engineering design, market analysis, or operations research, tend to be those which are performed best on the so-called "scientific" computer. On the other hand, the computations for current operations usually are simple sorting, collating, extensions, etc., and often are performed best on small modular units. Dr. Murdock's experience indicates that for some current operations purposes (e.g. some parts of production control) the IBM 407, for example, may be not only cheaper, but faster and better than the large scale machines. Thus, there is a good case for separating the current operations computing and data processing from the planning computations, and using equipment for each which is suited to its needs.

If this separation is made, then at least some thorny problems of scheduling computer usage may be more easily reconciled. That is, within the current operations network it is relatively easy to decide which of several computations should be first. It would not be so easy to decide between, say, a labor distribution or invoice preparation as part of current operations and an engineering design computation as part of the planning process. In those companies which are organized into process focused components, e.g., planning, operations, and control, rather than function focused components, such as manufacturing, marketing, etc., the equipment selection and scheduling problems are more easily solved. The relative urgency of problems arising from within any given network is easier to determine and the appeal would be made to a manager, say the manager of business planning, who would have more knowledge of those problems and their importance to the planning process.

Another result of this separation into process-oriented networks is the beginning of a recognition that computers and data processing systems well might be classified differently from their present classifications. For example, both IBM and Remington Rand now classify their computers according to "business" or "scientific." The evidence cited here suggests that they should be classified into equipment primarily for "current operations" which would consist largely of high speed electronic modular units equivalent to the present punched card tabulating machines and into equipment for "general purpose computation" which would consist of large or medium scale general purpose computers. These could handle most any of the more complex computations, whether they arise in scientific research, engineering design, market analysis, operations research, Industrial Engineering, or other.

A man cannot afford to tie up his conscious mind in consciously controlling his breathing, even though he technically can do so if he wishes and though breathing is vital to his existence. This type of control over many body processes is relegated to specialized portions of the brain or glands. In the same manner, business will learn that it cannot afford to tie up large scale general purpose computing equipment for similar routine operations, even though such computer could be so used and though such operations are essential to the business. It can be performed better by other less expensive equipments. In many instances this lesson is just being learned; some five hundred dollar per hour computers still are being used for one dollar per hour sorting or random searching.

The Univac File Computer, the RAMAC, the ERMA, the Reservisor, such work as that done by Murdock in designing the production control system, and by nature in designing all creatures suggest interim and ultimate solutions to business data processing. The large-scale general-purpose computer will be used less frequently for "all" data processing. It will be supplemented by specialized equipment for the many special purposes, all interconnected so that the objectives of the business are accomplished in some best manner.

Many top managers have commented on the difficulty of deciding whether a computer program is really successful. Before one can judge whether a broad business computer program is or is not successful one needs to understand the program and to have a clear understanding of the extent to which it can or does affect the assumptions and nature of his business. If it saves clerical costs, speeds computation, or solves linear programs, but fails to help to raise the business to a new way-of-life, then the program should be judged a failure. Abraham Lincoln once said: "The measure of a man is in the problems that surround him." You also can measure computer programs and their managers by the problems they try to solve. If these all are small, (payroll, inventory calculations, cost distribution) their measure is small and your success is minor. Since success is relative, a partial success is also a partial failure.

Peter Drucker read an early draft of this article and commented that the "jet in a Jenny" example made a good point for computers, but not without operations research (or its equivalent by any other name). Many men walked away from crashes in a Jenny, but very few from crashes in a jet plane. A crash with an expensive computer

installation can be far more costly than with a manual or tabulating system. OR is needed to help measure the risk, test the assumptions, and design the operation so that the crashes are cushioned or avoided. Very few Jennies remain, except in museums, and no one uses them commercially. Very few businesses will remain that manage progress so poorly that they do not keep pace of these innovations. However, there is no museum in which to place those that fail. Dr. Elmer Engstrom, Executive Vice President of RCA, has phrased this thought in different words (5):

> *That* business and *that* management—in the future—will be successful—competitively successful—if it understands the potentials of electronics, electronic computers and automation, if it reacts appropriately and puts the new tools into full use. Management will continue to be competitively successful only if it proceeds with understanding, recognizing that we are entering a new era—an era which includes as its foundation a new way to do business.

Throughout this article emphasis was given to the electronic computer as a new tool of management. It is important to close with the observation that this new tool brings with it the need for a whole new set of higher skills. These range from greater conceptual skill by the top manager, to greater scientific skill by the business analyst and functional specialist, and to keener operating skills by the middle and lower level managers. Without deeper understanding of each application and adequate theories of each business, the computer uses which were cited may not be feasible and more often will be uneconomic. Thus, the computer and related techniques, including OR, do not eliminate managers nor create "automatic management." Instead, they increase the level of skill required in all levels of management. These skills and the tools for using them in managing progress largely determines an enterprise's relative success in competition with other enterprises, and hence its profitability and longevity.

THE TALE OF A COW[2]

CHAPTER I—ANONYMOUS

LET us suppose that I am the owner of a cow. The purpose of a cow is to produce milk. If you turn the creature into a pasture and allow her to eat grass, she will produce many quarts of lacteal fluid. The process consists of eating grass, transmuting it into milk, removing the milk from the udder. However, you are infected with the system disease. You cease to be interested in milk. You hire inspectors to count the number and measure the height of the blades of grass eaten by your cow.[3] You count the number of steps she takes in the pasture. You time the number of occasions upon which she looks over the fence and test the volume of sound produced when she moos. Then you employ a bookkeeper to record these items, and various persons to make out forms for the guidance of the bookkeeper. At the end of the year you have a vast and entertaining volume of information, but you have added so greatly to the cost of your operation by systematizing in this manner that you lose money on every quart of milk that you sell. This, of course, is exceedingly modern and in accord with business practice, but you find yourself compelled to sell your cow to pay your overhead.

CHAPTER II—*by* M. E. SALVESON

SINCE you no longer produce and sell milk, you discharge your cow hands. This leaves you no applied direct labor, but $10 a month overhead in space rented to store the cow's records. Your bookkeeper tells you that this rental makes your overhead rate infinity (ten divided by zero is infinity), and that you can reduce overhead tremendously—from infinity to zero—if only you get rid of the records. You give them to the farmer who purchased the cow. He does not know that your data are worthless, so he accepts the whole truckload.

He cannot read; so he employs a scientist to help him learn what is in the records. Fortunately, you kept meticulous records; on analyzing them, the farmer's scientist learns that many things simultaneously affect how many quarts of transmuted lacteal fluid the cow can produce. The scientist, however, is bitten with a different disease—a strong psychological tendency toward optimization, compounded with an irrational passion for dispassionate rationality in seeking facts on productivity. In brief, he was looking for the high point on the milk production curve that corresponds to the low (sag) point on the udder.

By suitable analysis the scientist discovers from your data the number of blades of grass per day to feed the cow to get optimum milk production. Of course for the convenience of the cow and the cow hand, the scientist translates this number into the number of pitch-forks full. From your data on height of the grass, he learns the height (or maturity) of the grass at which it should be mowed for optimum utilization of the cultivated lands and production of milk. Your data on the number of steps the cow had taken yield to the scientist excellent information on the optimum percent of the time she should be roaming (exercising) in the pasture or quiet in her stall. Your records on where she had looked over the

[2] Reprinted with permission from "Computers and Automation," August 1955, published by Berkeley Enterprises, Inc., 815 Washington Street, Newtonville 60, Massachusetts.

[3] Note by M. E. Salveson: It is understood a British scientist has indeed developed a device for counting the number of blades of grass a cow eats.

fence most frequently and mooed with the greatest gusto gives the scientist clues as to what grass is most palatable, while also nutritious. This increases her protein intake and butterfat output.

In no time at all the farmer has the cow producing so much milk that even with an expensive, non-transmutive (he did not personally transmute even one drop of the lacteal fluid) scientist on the overhead payroll, the unit cost of milk was greatly reduced. He then asks the scientist to study if he should expand his herd and how rapidly. In that study he also finds the optimum amount to reduce milk prices so as to make profits soar and stay at their maximum.

As the size of the udders, the herd, and the profit grow, the farmer is so impressed with the scientific method that he has the scientist set up a regular scientific business research group to look into all phases of the business and to advise him how to manage it more profitably. This new research leads to more profit-making discoveries that are not at all obvious and quite unexpected even to this experienced and seasoned farmer. The scientist discovers that many managerial problems even of the cow business are so intricate that only by scientific methods can an optimum course of action be found. For example, he finds that mathematical computing methods are necessary to obtain the minimum cost diet (food mix) that still provides required nutrition, to determine the shortest routes for his fleet of new delivery trucks, to determine the optimum amount and mix of dairy products to carry in his optimally located warehouses, to select the most profitable mix of butter, milk, and other dairy products to make from a given batch of raw milk, to find the least cost daily work schedule and amount of equipment to purchase, to determine the most productive and profitable crop rotation plan for the cultivated lands, to compute what products should be sold now and what should be held for expected price changes, to determine the optimum balance between size of the herd, milk processing facilities, delivery fleet, and market potential. There are, naturally, other problems being solved scientifically, but they are too numerous to list here. Indeed, the farmer's customers now are too numerous to list and the problems too large to solve manually, so that he handles these with the electronic data system the scientist determined was optimal for the job.

Of course, the farmer's overhead rate, with all that scientific research, now is sky high but he does not mind. He is in business to maximize profits and not to minimize overhead costs. This, of course, is not very modern and not at all in accord with business practice, but it does pay for more vacations to California for the farmer and for his management scientist, but not for you nor your bookkeeper.

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Instrumentation for Automatic Data Processing in Motion-Time Research

by **DELMAR W. KARGER**

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ELECTRONIC computer techniques can do much to speed up research in Industrial Engineering. To discuss the full range of possible applications would require volumes.

INTRODUCTION

This paper will be restricted to a discussion of some of the problems and a report on possible approaches to the application of automatic data processing to research on reaches and moves. It is based in part on a feasibility study prepared by a research organization* for the Methods-Time Measurement Association for Research and Development. While the data primarily resulted from a study of problems regarding the manual motions of reach and move as associated with MTM research, the discussion contains much information generally applicable to automatic data processing.

In order to derive the full benefit of automatic data processing equipment, it is necessary to automatically generate input signals. Therefore, a detailed investigation was carried out by the research engineers to determine possible means of generating such input signals for reach and move research.

EQUIPMENT AND MATERIALS

One of the more practical approaches to this problem involves the use of miniature accelerometers. It is possible to purchase such units commercially and to package three of them into approximately an inch cube and thereby measure acceleration simultaneously in the X, Y, and Z axes. This combination of accelerometers is identified as a triaxial unit and could be clamped to the operator's wrist as shown in Figure 1. Fine wires could then run from the accelerometer, up the operator's arm and to the input circuits of automatic data processing equipment.

Figure 2 illustrates schematically the essentials of a seismic accelerometer. A mass is suspended or constrained by two springs or other mounting which permits its displacement when subjected to accelerations. The amount of displacement is then measured by causing the displacement to vary an electrical quantity such as resistance, reluctance, or capacitance. Within the past few years there have also been constructed units making use of piezoelectric crystals or other materials exhibiting similar properties. Such crystals and materials generate a voltage that varies with the pressure to which the substance is subjected.

PROBLEMS OF EQUIPMENT APPLICATION

There are some rather difficult problems associated with the use of accelerometers for the purpose indicated. One of these is the effect of gravity. The device shown in Figure 2 is designed to measure acceleration in the hori-

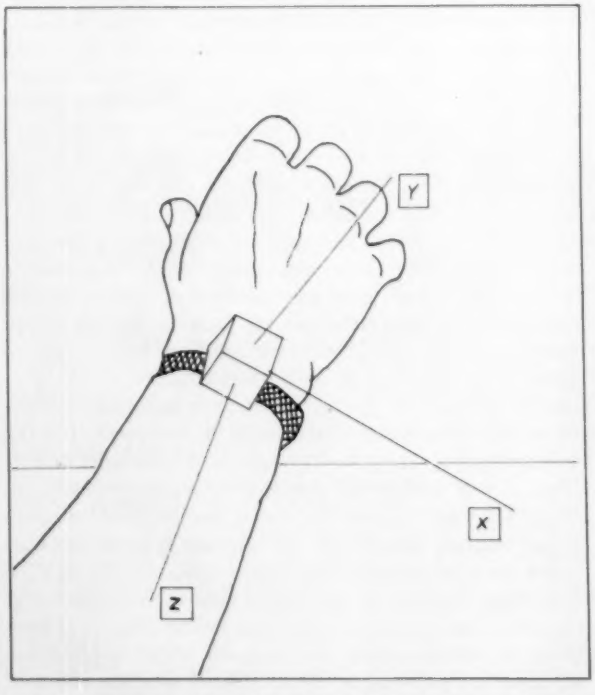

FIG. 1. Dummy Triaxial Accelerometer with Axes of Sensitivity Indicated

* Feasibility Study for MTM Association, Electro-Mec Associates, C. C. Perry, Research Consultant, 9/24/56.

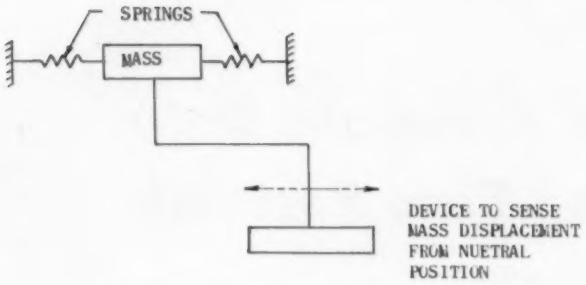

FIG. 2. Simplified Sketch of Seismic Accelerometer

zontal plane. If it is rotated clockwise 90°, it will indicate an acceleration of 1.0 g—the acceleration of gravity. If it is rotated 90° counter-clockwise from the position shown, it will indicate −1.0 g acceleration. This again is due to the effect of gravity.

It is obvious that during the performance of reaches and moves, that the plane of the wrist and, therefore, the *XZ* plane shown in Figure 1 will vary from a ground reference plane, such as the top of the workplace, causing the individual accelerometers in the triaxial unit, all three of them, to be variously affected by the acceleration of gravity.

Figure 3 shows the percent of error that would occur due to this effect for various angles between the gravity axis and the direction of the acceleration for various levels of wrist acceleration. It is possible to have the operator go through several "trial runs" of the reach or move to be evaluated, and either mechanically adjust the *XZ* plane to minimize the effect of gravity or else balance out the effect of gravity for the average condition electrically. The mechanical adjustment could be accomplished by using a ball and socket mounting. The electrical balancing procedure is, in the author's opinion, to be preferred since each balancing can be accomplished in less time and secondly, it probably will yield greater accuracy since each individual accelerometer can be balanced to zero for each position to be evaluated and from the balance readings derive the average balance reading or adjustment to be used. It was estimated by the research engineer that the effect of the balancing action would be as shown in Figure 4. In any event, it is believed that this effect can be minimized, probably to the extent that the maximum error introduced would be in the order of 5%. This is well within the permissible limits normally allowed for time and motion study analysis and probably is only slightly larger than the inherent magnitude of error in the accelerometer itself (approximately 3% to 5%).

Another small error that would need to be evaluated in the execution of this system would be the effect of the rotation of the arm about the shoulder which would cause an apparent outward acceleration and also the effect of the rotation of the wrist about the axis of the forearm which again would generate another extraneous acceleration to those which the researcher desires to measure.

Commercial accelerometers of the size and types indicated can be purchased for a unit cost varying from approximately $225 to $325 each. Three of these can be packaged in less than an inch cube. Their combined weight would be well under one ounce. For example, one such package of three would have a dimension of 7/8″ ×1/2″×3/16″ and would weigh only 2½ grams (approximately 1/10 ounce).

HOW TO USE THE SIGNALS

By this time many of you are wondering what would happen to this signal and how it would be used. Figure 5 shows in block diagram form, a computer or data processing system capable of automatically supplying data from these signals for research on the motions of reach and move.

It should be mentioned that block diagrams such as this are the "stock and trade" of people involved in explaining and designing data processing systems. They make it possible to talk about a very complicated subject in a relatively simple manner. Electronic engineers often also use the block diagram in combination with a logic diagram as a base for constructing the electronic schematic diagram ultimately needed.

The signals obtainable from the accelerometers are weak and must be amplified. This is shown in the block diagram by amplifier *Ax*, amplifier *Ay*, and amplifier *Az*.

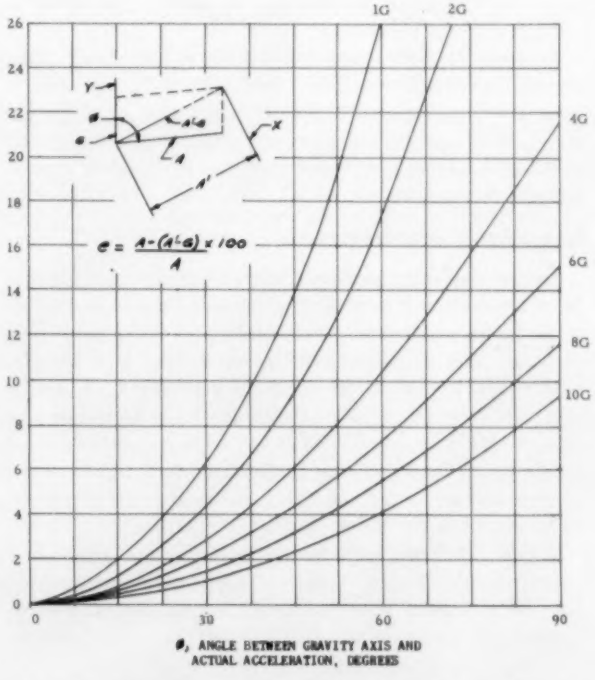

FIG. 3. Percentage Errors Encountered by Suppressing the Acceleration of Gravity from the Total Indicated Acceleration

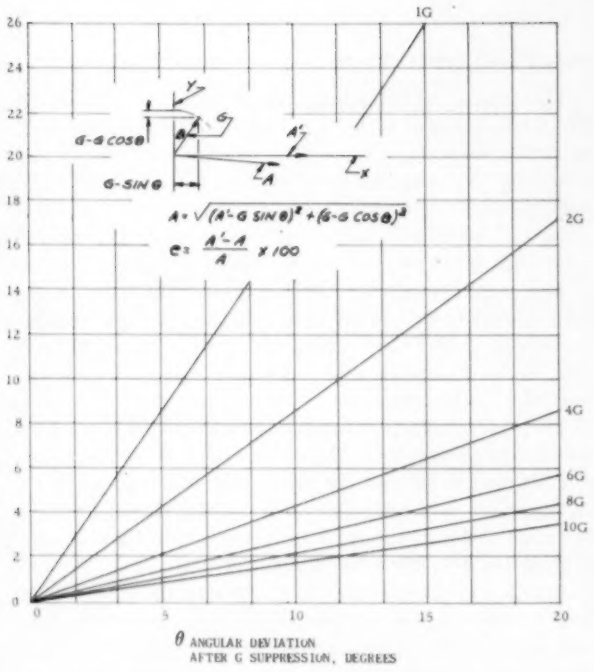

FIG. 4. Maximum Errors for Technique of Suppressing Gravity Components Along Each Axis of Accelerometer Sensitivity

These can easily be commercial amplifiers since many of those now being built for use in computer systems have relatively linear response curves and are stable in operation. It is technically obvious that we must be careful not to amplify one signal more than another, otherwise we will have introduced an additional error. This means that we must either manually or automatically adjust the level of amplification for each of the three amplifiers so that they are exactly equal to each other. It is customary to make this adjustment manually prior to the start of a data run. The manual system of balancing the three amplifiers is simple. Automatic balancing can be accomplished, but it is much more difficult to execute and would necessitate the design of special circuitry not obtainable as a commercial product.

Based on the fact that the research engineer would be interested in the resultant magnitude of acceleration rather than the individual vector accelerations in the X, Y, and Z axes, it would be necessary to run the signal through a unit identified as Synthesizer A.

Since accelerations are vector quantities, they have magnitude and direction. In order to combine them we must combine them vectorially. There are several schemes whereby this can be accomplished. One such scheme is shown in Figure 6. Essentially this involves taking the square root of the sum of the squares of each acceleration magnitude to obtain the resultant magnitude—the same as the magnitude of the resultant acceleration vector that would be obtained by vector addition. Most of the circuitry involved again can be obtained commercially. The accuracies obtainable are higher than 95% (5% inaccuracy).

Balancing and calibration would, however, be necessary. This is again in addition to the basic equipment indicated. Similar remarks apply to the remainder of the basic equipment shown in the block diagrams.

The output signal from Synthesizer A could be recorded on an automatic curve drawing device. Such units are also commercially available from over six different firms.

ADDITIONAL DATA NEEDED

In addition to the research engineer needing data on the magnitude of the resultant acceleration vector involved in the performance of reaches and moves, he also

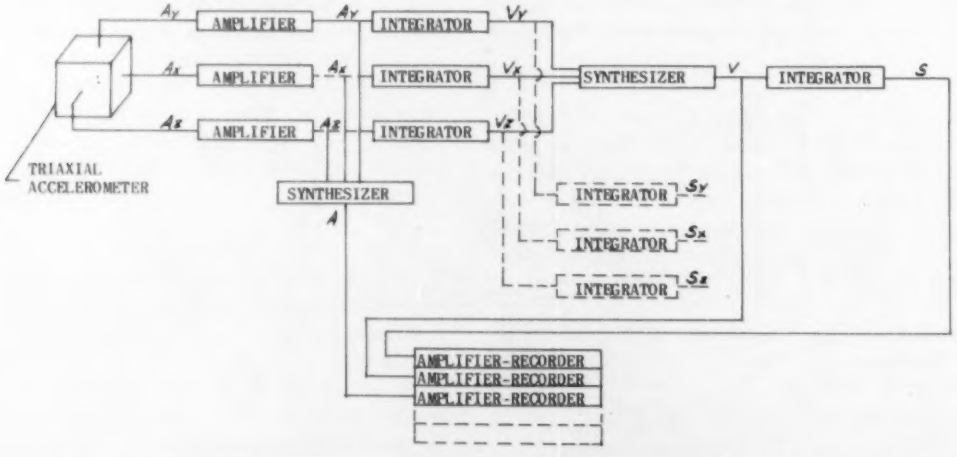

FIG. 5. Functional Block Diagram of Data Processing System Based on Triaxial Accelerometer

must obtain data regarding velocity and the distance traveled. You will recall from your calculus that velocity can be obtained by integrating the acceleration once, just as conversely it is possible to obtain acceleration from velocity by differentiating once with respect to time. Referring back to Figure 5, you will note that the X, Y, and Z accelerations are integrated to obtain the velocities in the X, Y, and Z axes. The integration problem involved can be accomplished electronically in a very simple manner such as through the use of a Miller integrating circuit.

Ordinarily the research engineer would be only interested in the magnitude of the resultant velocity. These individual velocities, therefore, would again be passed through a synthesizer similar to that previously described to obtain the magnitude of the resultant velocity, which in turn could be recorded as shown by using exactly the same instrument which records the acceleration. These recorders are multi channel recorders. A four channel recorder could be obtained for approximately $4,000 to $5,000.

Integrating the velocity V with respect to time as shown in the block diagram obtains a measurement of the distance traveled. This also could be simultaneously recorded as shown in Figure 5.

Should the research engineer be interested in distances traveled in the X, Y, and Z axes, it is possible to obtain these data by means of the circuitry shown in the dotted lines on Figure 5.

The Feasibility Study indicated that the system shown in Figure 5 and as generally described to this point, could be constructed for $18,000 to $28,000 and would have an overall accuracy of 10%.

I concur that the forecast accuracy can be achieved, in fact it should not be too difficult to bring it to approximately a 5% limit. However, based upon personal experience with the cost of computing systems, the cost forecast appears too conservative for covering the cost of building and "debugging" the system described. The total cost would probably range from $40,000 to $50,000 before it would be working on a practical basis. It might, however, be possible to begin to make some data runs prior to the expenditure of the total sum indicated as being required.

PRACTICAL LIMITATIONS

The system described has some practical limitations which were not delineated by the feasibility study. It would be reasonable to do laboratory work next to the computer, but one certainly wouldn't want to take the computer out into a factory when securing industrial data. Industrial data are absolutely necessary if practical time data are to result from the research.

This would necessitate recording the output of the triaxial accelerometer on some intermediate storage medium such as magnetic tape. The necessary amplifiers and the tape recorder could be small enough to make it a practical approach to this problem.

The intermediate storage approach would also help solve another problem—that of research on simultaneous reaches and/or moves. Triaxial accelerometers could be clamped on each wrist and their outputs simultaneously recorded. The output from each unit could then be separately fed into the computer.

Let us take another look at the computer. Digital data can only be obtained by human interpretation of the output graphs, or by electronic conversion with special equipment.

Automatic analog to digital conversion is relatively simple, providing such conversion is only needed for a reasonably discrete number of points on the curve. However, this makes necessary still another piece of data processing equipment.

The output of the converter would then logically be recorded in code on some medium permitting later processing of the data. If printed out (not recorded in code) on a high speed printer (expensive approach) it would be of little or no advantage to the engineer over the charts, since further processing of the data would need to be manual. If, however, we recorded the digital data in an acceptable code on magnetic tape or other suitable recording media such as punched tape or punched cards, it could later be fed into a digital computer for final and

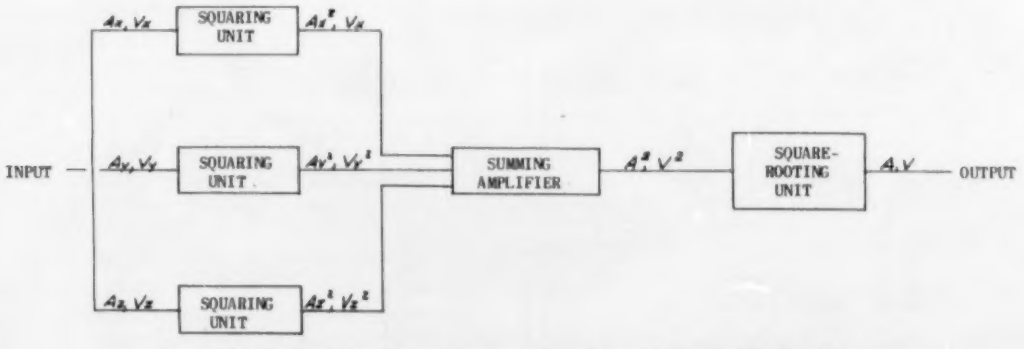

FIG. 6. Synthesizer Employing Electronic Squaring and Square-Rooting Units

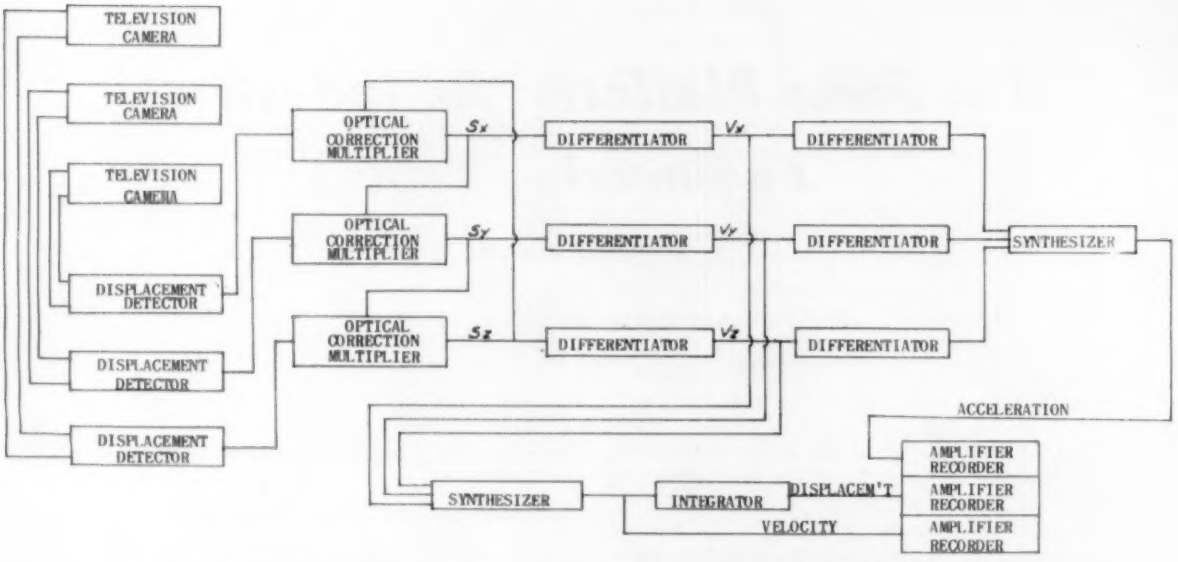

FIG. 7. Functional Block Diagram of Data Processing System Based on Three Television Cameras

complete automatic data processing.

The Feasibility Study reported on several other methods of obtaining an input to the computing system. One of these involved the use of three motion picture cameras in combination with photocells, lights and other devices. Another approach involved the use of variable resistances tied to the operator's wrist. The final suggested approach involved the use of three TV cameras. One of these TV cameras would be mounted in front of the operator and aimed toward him, another off to the side and aimed at the workplace, and the third mounted above and aimed down at the work area. A block diagram of the proposed analog data processing system would be similar to that shown in Figure 7.

The system described in Figure 7 is more complicated than the accelerometer approach, would cost more in terms of equipment required and would very obviously cost more in terms of engineering labor to design, build and "debug" this system. It is my personal opinion, however, that this system is practical and might ultimately be of more value for this type of research than the system using Accelerometers. The deciding feature as to which system to execute would probably involve the amount of money available.

UNOPAR

It is interesting to note that Dr. Gerald Nadler at Washington University has attacked the input data problem in still another manner, yet apparently achieving a similar result (1), (2) and (3). His approach is to attach a sound source (Miniature speaker driven by an oscillator) to the operator's wrist and make use of the doppler effect when picking up the radiated sound with a microphone.

For those unacquainted with this effect it can be simply explained by citing a common experience. Most of us have stood at a railroad crossing and noticed that the train's whistle appeared to have a higher frequency when the train was approaching than when it was traveling away from the listener. The frequency change can be related to velocity. This same effect was used by U. S. Scientists to calculate the speed of Sputnik.

It now becomes obvious that usage of three microphones in place of the three TV cameras previously mentioned could be used to secure input data of the analog variety. The actual block diagram of the associated data processing system, of course, is somewhat different from those described, but not significantly different in degree of complexity. Dr. Nadler, is in fact at present, attempting to solve the analog to digital conversion problem on an automatic basis to eliminate human or manual interpretation of the curves.

CONCLUSIONS

It can be concluded that computers such as described are 1. practical based on today's developments 2. the cost required is nominal, in fact low, when compared to the cost of general automatic data processing systems and 3. such units will materially help to accelerate much needed Industrial Engineering research.

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The Force Platform: An Industrial Engineering Tool[1]

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and **W. H. M. MORRIS**[3]

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THE INDUSTRIAL ENGINEER in his attempts to improve working standards and increase production has worked for many years in the area of empiricism and intuition. He has resorted primarily to time as the basis of all his measurements of human activity. Any differences in physiological requirements have either been ignored or dealt with in a haphazard way by applying crude and inaccurate allowances. The Force Platform may offer the Industrial Engineer the opportunity of making decisions not only by using time but also physiological cost and actual work as expended by the worker.

Techniques of measuring physiological cost have progressed from complex direct calorimetry methods to the present indirect way of determining the calorie cost from the quantity and oxygen content of the expired air. Even this newer technique requires that the worker wear a mask or mouthpiece attached to a bag or meter. With such impediments it could hardly be expected that the worker would simulate the actual unrestricted working conditions. In addition, this equipment with all of the devices needed is expensive and requires careful handling. The analytical procedure at best is time-consuming and subject to errors.

The Force Platform on the other hand permits the worker to perform his task in a natural environment without being hampered by face-masks, hoses, wires and all of the other usual paraphernalia. By adding to the platform electronic computers which are available on the market, it may be possible to obtain task values directly without delay.

HISTORY OF THE FORCE PLATFORM

The first evidence of a platform of the type discussed here was Lauru's "Effort Detector" constructed in 1949 (3, p. 229). He improved upon his first design at a later date, when he joined the research team of Professor Soula. The results of their project have been presented to the French Academy of Science as well as published in several periodicals.

The apparatus as used by Lauru is illustrated in Figure

FIG. 1. Force-Platform and Recording Equipment Used by Lucian Lauru

[1] This study forms part of the Purdue Farm Cardiac Project, AES Project No. 712, under the direction of Dr. L. S. Hardin, sponsored by the Indiana Heart Foundation and American Heart Association. Authorized for publication as Purdue University Agricultural Experiment Station Paper Number 1201.

[2] This material is extracted from the Ph.D. dissertation of the senior author, which was presented in partial fulfillment of the requirements of the Department of Industrial and Management Engineering, State University of Iowa, Chairman, Professor J. Wayne Deegan.

[3] The authors acknowledge the assistance given in this study by J. B. Liljedahl, Agricultural Engineering Department, Purdue University, and J. E. Wiebers, Biological Sciences Department, Purdue University.

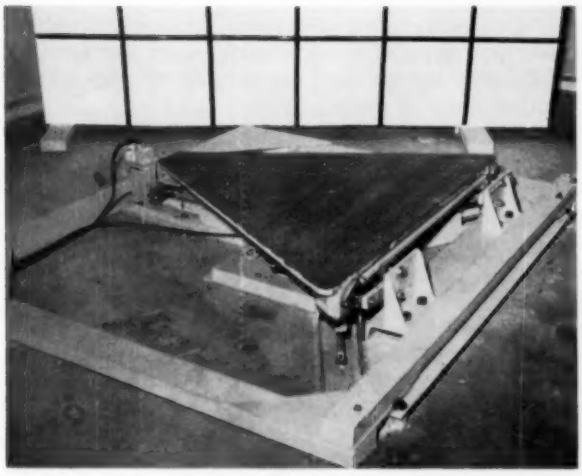


FIG. 2. The Purdue Platform

1 (4, p. 18). In the background is a console "B" containing amplifiers and oscilloscopes with photographic recording equipment for the purpose of amplifying and recording the forces. The small unit to the left, "C," is a timing device which produces a periodic impulse on an oscilloscope. The platform, "A," which a worker occupies while doing a task is shown in the foreground and according to Lauru:

> The "effort detector" as developed by us makes use of the properties of piezo-electric quartz, which converts variations in pressure into proportional variations in an electric current. The detector registers in three component planes, the reactions caused by muscular efforts brought into play in the execution of a movement. These are recorded, after amplification, on oscillographs, and a permanent record of the oscillations is made with a five-lens camera (3, p. 301).

Since the time of Lauru's initial research, it is known that at least several other platforms have been developed. Dr. Brouha, of the Haskell Laboratory, E. I. Du Pont de Nemours and Company, is using a Lauru Platform for his physiological studies.

A Force Platform is under development by the College of Aeronautics in Cranfield, England. Another platform is being used in the Department of Anatomy, Oxford University. This latter device consists of a square aluminum platform suspended by wires from cantilever beams. To the beams are attached conventional strain-gages for detecting forces.

The Force Platform designed and built by the authors under the auspices of the Purdue Farm Cardiac Project is illustrated in Figure 2. An entirely new approach was made in the design of this platform resulting in an extremely sensitive platform with excellent qualities at a modest cost. Details of the platform are to be fully covered in a later article, but it can be briefly pointed out that this platform differs from other platforms primarily in the method of uncoupling and detecting the forces. Further, the force values are transcribed on a conventional three-channel Brush Recorder rather than the more complicated oscilloscope.

CURRENT INTERPRETATION OF PLATFORM DATA

Lauru has not, to our knowledge, published data correlating physiological cost or work with the platform data but has published interpretations concerning the effort required for a number of tasks. In these studies he apparently makes a direct inference from the platform data, i.e., the smaller the force-time integral plotted, the smaller the amount of effort required for that particular task.

A typical example would be his evaluation of Gilbreth's classic study of bricklaying. Figure 3 shows the plot made by the traditional method of bricklaying. Figure 4 shows the Gilbreth method, and Figure 5 shows the improved method according to Lauru (4, p. 18). Apparently his evaluation is made upon the basis of the area beneath the curve.

Many other task plots have been interpreted by Lauru, some contradicting accepted motion study practices. Lauru, however, recognizing the necessity for further investigation states:

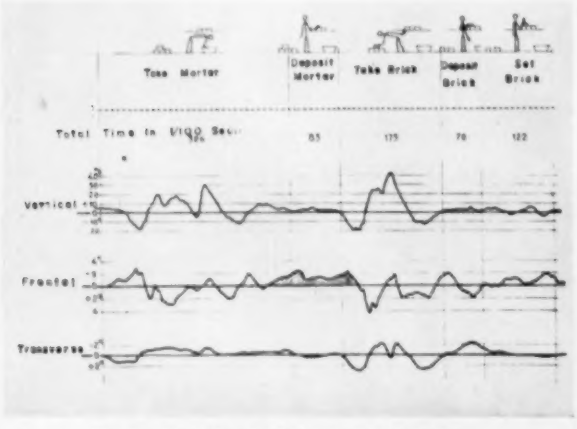


FIG. 3. Traditional Method of Bricklaying

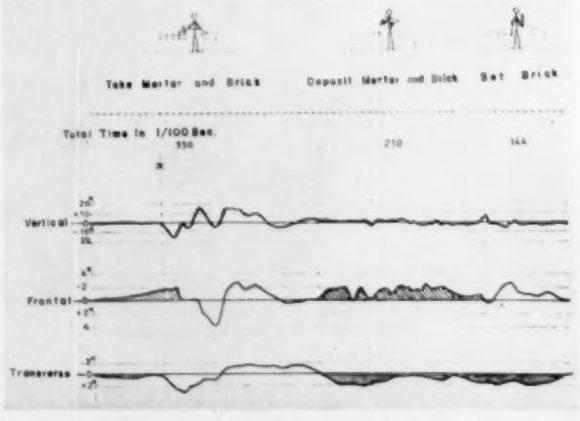


FIG. 4. Gilbreth Method of Bricklaying

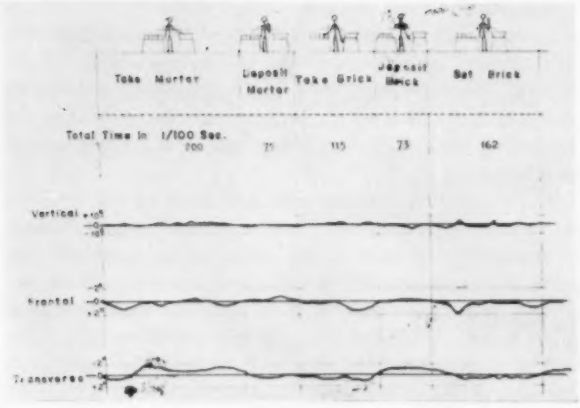


FIG. 5. Improved Method of Bricklaying

Oxygen consumption can, however, at present be measured only under laboratory conditions . . . further research will be necessary into the relation between oxygen consumption and the effort diagrams obtained . . . (3, p. 370).

EXPLANATION OF THE MECHANICS OF THE PLATFORM IN USE

The value of the platform will no doubt depend upon a thorough understanding of the platform mechanism without reference to experimental data. The measurement obtained from the platform will be explained here as interpretations of the dynamics of platforms have apparently been the source of confusion.

For the purpose of analysis it will be clearer if a simplified schematic of the platform with its associated recorder is considered as in Figure 6a. The platform is supported by a cantilever beam which represents the compressive characteristic of the transducer. A force on the beam causes a deflection of the recorder pen which is dependent upon the amplification factor of the recorder and the spring constant, k, of the beam.

Assume the beam is pressed downward by a gradual force, F_1, equal to the weight of the platform and man (Figure 6b). The potential energy stored in the spring then is expressed by Area I on the work diagram and by the equation:

$$\text{Work} = \frac{F_1 \Delta y_1}{2} \qquad \text{Eq. 1.}$$

The first situation to consider is the subject seated on the platform doing a typical task such as operating a foot lever (Figure 6c). If the leverage arms are equal, $F_p = F_w$ if friction is ignored. Next consider that the operator is pushing down gradually on the pedal just enough to sup-

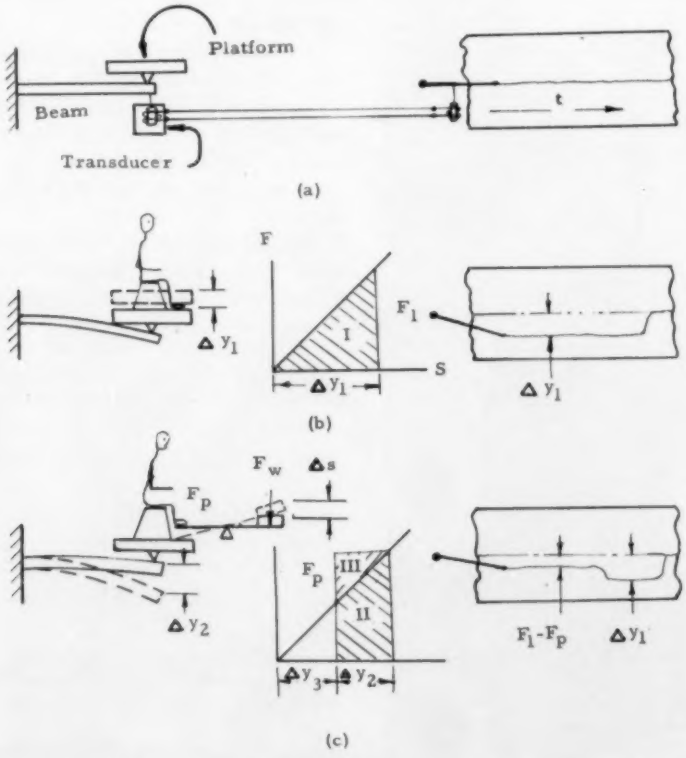


FIG. 6. Mechanics of the Platform in Use

port the weight but not enough to put it into motion. This would be the same as removing a load equal to F_p from the platform. The beam spring would then give up energy shown on the work diagram by Area II. The following equation represents the work done by the operator:

$$W_1 = \frac{F_p \times \Delta y_2}{2} \qquad \text{Eq. 2.}$$

The work can be determined from the platform if the spring constant, k, is known. Hence:

$$W_1 = \frac{(F_p)^2}{2k} \qquad \text{Eq. 3.}$$

For a beam loaded with a maximum load of 50 pounds and having a corresponding active deflection of 0.040 inches, the manual work is:

$$W_1 = \frac{F_p \times y_2}{2} = \frac{50 \text{ pounds} \times 0.040 \text{ inches}}{2}$$

$$= 1 \text{ inch-pound} \qquad \text{Eq. 4.}$$

which is negligible.

This is the only work directly measureable from the platform alone but additional work is performed by lifting the weight through a distance Δ_S:

$$W_2 = F_w \times \Delta s = F_p \Delta s \qquad \text{Eq. 5.}$$

$$W_{\text{total}} = \frac{F_p \Delta y_2}{2} + F_p \Delta s = F_p \left(\frac{\Delta y_2}{2} + \Delta s \right) \qquad \text{Eq. 6.}$$

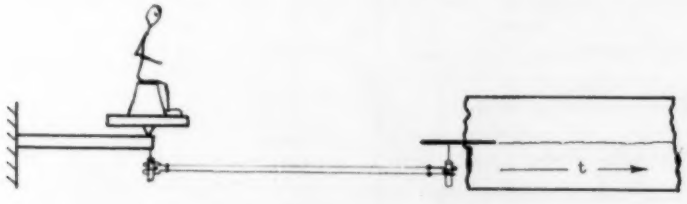
F_p is increased by a small amount required to accelerate the weight; however, this quantity is small enough to be neglected. Using for example a displacement force of 50 pounds exerted on the platform and a five-inch displacement, $F_p \Delta_S = 250$ inch-pounds which is considerably more than the work that can be determined by the spring characteristics.

F_p is obtainable from the platform but it is important to recognize that there is no way of getting the quantity Δ_S from the platform and without this the total work cannot be determined. The same argument will hold for each of the other two components of the force being exerted.

Since the recorder gives a continuous record of the forces on a time axis, the graph could be misinterpreted as the integral of an "impulse" which is defined as:

$$\text{Impulse} = \int_{t_1}^{t_2} F dt \qquad \text{Eq. 7.}$$

The weakness of such an interpretation is demonstrated if we consider a subject seated on the platform with the instruments zeroed as in Figure 7a. A weight, W, placed in the subject's hands (Figure 7b) will in turn deflect the pen. The subject may sit in this position for several hours while the recorder generates a very large force-



(a)

(b)

Platform

Brush Oscillograph Record

FIG. 7

time curve. While the worker may be uncomfortable and incur physiological costs, it would be unreasonable to explain this integral as "impulse."

It is, therefore, evident that the platform measures force and force alone. This force value for any instant is given on the recorder and the paper tape is only a continuous time record of the force, and no more.

CONCLUSIONS

It appears evident from the analysis of the platform dynamics that it would be difficult to justify any straightforward analysis of the platform tracings as has been done. Either the displacement of the body members must be kept constant for any given task situation or some means of measuring the displacement must be incorporated. At first sight it might seem that the platform could not be applied to the evaluation of work. This is not necessarily true, for in many situations the distance can be measured directly, while in other cases there are well-established Industrial Engineering techniques suitable for measuring displacement. In fact it would seem that the Force Platform may be the missing link in the full application of such techniques as the Chronocyclograph, stroboscopic camera, micromotion study, and the more recent development, the Universal Operator Performance Analyzer and Recorder, "UNOPAR" (6).

The immediate future of the Force Platform is no doubt in the laboratory, but it could obviously fit the industrial situation. The following possibilities give some indication of the broad applications of the platform.

1. Use of the Force Platform could probably indicate the onset of physical fatigue by indicating lack of coordination and increased use of an ability in worker performance.
2. The Force Platform may enable the detection of differences in work methods more precisely and more easily than present physiological measuring methods.
3. The Force Platform may be useful in indicating optimum arrangements of controls and tools.
4. The Force Platform could be used to compare time-study rating methods.
5. The Force Platform might be used to develop an objective system of rating for the skill of the operator.
6. The Force Platform suggests a relatively simple method of classifying jobs by physiological cost.
7. The Force Platform may offer opportunities for determining the optimum length of rest periods as well as the time of their occurrence.
8. The Force Platform might be proposed as a technique for selling method improvements to workers.
9. A possible use of the Force Platform would be to determine how jobs should be split among crew members or among assembly-line workers.
10. The Force Platform may be found useful as a means of determining industrial efficiency.
11. The Force Platform with UNOPAR could provide a complete micromotion activity record including the human dynamics.
12. The Force Platform records provide a time base for micromotion study.
13. The Force Platform provides a time base for measuring psychological reaction time. Changes in reaction time and in the uniformity of motion could be developed into objective estimates of fatigue.

It is not the purpose here to pursue the possible applications, but it can be said, however, that greater knowledge of the Force Platform may well lead to many improvements in the utilization of human effort.

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AS WE continue our growth as a learned society, we must increasingly search for better weapons with which to fight our common enemy—professional ignorance and ineptitude.

A father recently complained because the engineering curriculum his son is studying is so different from the one which had equipped him well to succeed in the world. "The program was sound and practical when I took it," he said. "Why did you have to tamper with it?"

He failed to realize that today's education is for the next forty years of professional life, not the last forty. Just as his education prepared him for his life, his son's education must prepare the son for the new era in which he will live.

It was only yesterday, in the calendar of eternity, that we were an isolationist nation. Our economy had rapidly followed rivers and lakes since they afforded the easiest corridor of transportation. And settlements grew along these corridors and used water for power.

Industrial Engineers were unheard of. In fact, the only engineers worthy of the name were military engineers. Men who retired from the Army became civilian, or civil engineers, and our profession started.

Steam power exploded into the Industrial Revolution, and with it engineering splintered into specialties, and the roots of narrowness were planted.

Cheap labor and no taxes, by today's standards, made it possible to be successful by manufacturing any wanted item. Demand far outstripped supply, and industries succeeded whether they were wantonly wasteful or not.

With World War I came the first realization that victory belonged to the nation which could produce the largest quantity of war materiel and deliver it where it was needed, just ahead of the need. No longer could industry "fly by the seat of its pants" and survive. The war lessons, painful, and often wasteful, were projected into the next decade, and the "efficiency expert" of the twenties was born.

Just how much we in Industrial Engineering still suffer from the charlatans who were among this group we may never know. But we survived, and after several abortive attempts to start a professional and learned society for our profession, AIIE was born. In ten short years we have achieved our current status as the technical society for professional Industrial Engineers.

Our phenomenal growth into a professional engineering society in less than ten years has projected us into new areas of service, new responsibilities to our members, our industries and their employees, and to our nation.

As 1958 dawned we were 6412 members strong, located in 80 chapters in 32 states, with Ohio having the largest number of chapters: 8. Our largest chapter is Metropolitan New York with 384 members; Los Angeles is

second with 262; and Cleveland is third with 223.

It is evident that we have an Herculean task ahead: to upgrade in knowledge and stature all of our individual members; to push into areas where we should be and aren't; and to lead the profession by defining our terms, explaining our techniques, improving our methods, and creating totally new processes of analysis and synthesis to answer the increasingly complex questions posed by our industrial operations. More importantly, we must learn to predict, accurately, tomorrow's sales, production, labor costs and methods.

This is our new responsibility and our charge as we continue to grow.

The first in what we hope will be a series of courses for Industrial Engineers will start through co-sponsorship with Marquette University of a short course on Linear Programming to be held April 28–May 2.

Our several national committees are hard at work, but we still have weaknesses. There are 39 cities of more than 100,000 population in which no AIIE chapter exists.

There are 46 accredited Industrial Engineering curricula, including options, but only 35 student chapters are now part of our organization.

The strength of every organization is in its grass roots. We grow through individual initiative, or we die. Look critically at the area where you live and work. If there are engineering schools where chapters should be started, contribute your time and energy toward that worthwhile end. If there are cities which should have a chapter and can support one, spark a drive to get it started.

As our professional organization, AIIE can increase the layman's respect for each individual member by building our Industrial Engineering profession into a science.

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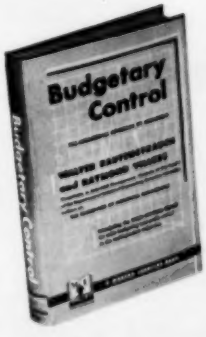

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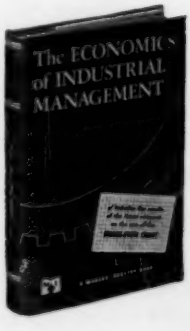

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Reader Comments

A GRAPHIC METHOD FOR FINDING REQUIRED NUMBER OF TIMESTUDY READINGS, by B. L. Hansen, *Journal of Industrial Engineering,* May-June, 1957.

Mr. Hansen is to be commended for proposing a system that recognizes the fallacy of using a single range for estimating dispersion. Also, I agree with his thinking along the lines of "how much" accuracy. We know too that the use of small sub-groups of a sample to determine the additional number of samples to be obtained is common practice in statistical quality control systems (5).

But the use of such a system in timestudy is limited. In the writer's opinion, it is also hazardous. Before such a system can be used by the Industrial Engineer, other important factors must be considered.

According to Phil Carroll, one of the reasons for so many wage incentive grievances is "lack of coverage" (1). To obtain "coverage," we must put our sights on the non-repetitive operations. The highly repetitive is easy to measure.

The best information I have indicates that 86 per cent of industry is in plants of about 100 people and 91 per cent in plants of 500 or less (3). To wait for a "statistically" correct number of readings means that in many instances standards will not be set. For this reason I say that the application of such a system is limited. Shall we say it can be used only where we have been setting our "rates" on the easy to measure, repetitive work.

As for the hazards, I submit the following:

1. To begin with, we must consider cause—not effect. Dispersion in watch readings is caused in the main by the person being studied. Such dispersion will vary between elements within the same timestudy. Interest and effort are not that constant. Too, time of day and presence of the timestudy man are two other causes of variation. Another I particularly want to point out is that the *person being observed might be changing his method.* This certainty must be recognized. Different people doing the same type of work will use different methods, thus I fail to see how statistics will aid in sorting out these inherent variations. They can do nothing more than provide a "crutch" for the timestudy man—give him an easy solution to a complex problem—supply a mathematical way to make the error of "averaging" conditions that should be analyzed.

Too many times, we draw a curve that represents an average when, in reality, we have a family of curves. What is included in the average is anybody's guess. Using the average is merely avoiding the problem of rating, element study and analysis of work content. It is an attempt to apply a mathematical formula to obtain consistency. For instance Ralph Presgrave points out, "While, in the main, consistency is presumptive indication of rapid and competent operating there are too many conflicting elements to permit generalization to the extent of embodying the idea in a formula" (4).

2. Mr. Hansen suggests that the chart could be superimposed on a portion of the timestudy rating form. Perhaps, such a procedure will tie down the variations in a "rate setting" or single timestudy method. However, the danger here is that it may create clauses in our contracts that attempt to define the mechanics of timestudy (2). Adoption of such a procedure could really lead to a clause in your contract that would specify the number of watch readings that must be taken as well as the mechanics of computing the time for your elements.

The only answer as I see it is to employ the Standard Data approach after good, sound timestudy training.

My intent is not to criticize Mr. Hansen's efforts. But he recommends a system that can, without intelligent appraisal, lead to erroneous conclusions and inconsistent practices. I speak up only because some who search only for a remedy—another tranquilizer—may rush into applying his "cure all" without recognizing that the approach attempts to unravel effects—not causes.

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—Kenneth J. Barth, Staff Supervisor, Incentives, American Car and Foundry Division, Berwick, Pennsylvania.

IN MEMORIAM

DWIGHT DE WITT GARDNER
1898-1957

BORN March 24, 1898 at Columbus, Ohio. Died December 17, 1957—Boca Raton, Florida. Attended Ohio State University, graduating in 1921 with a degree in Business Administration and a minor in related Engineering subjects. Member Phi Gamma Delta; Scioto Country Club (Past President); Ohio Society of Professional Engineers; National Society of Professional Engineers; Engineers Club of Columbus, Ohio; Free and Accepted Masons, David Kinsman Lodge; Scottish Rite; Aladdin Temple Shrine; Trustee of First Community Church; Member of Audit and Finance Committee Ohio Trucking Association; Listed in *Who's Who of the Midwest*; Charter Member of American Institute of Industrial Engineers; an ardent fisherman, one of the first to take up spin fishing when it was introduced to this country.

Survived by his wife, Esther B.; a son, 2nd Lt. William with U.S.A.F. in Alaska; and a sister, Mrs. W. B. Arne of Washington State.

Employed by Commercial Motor Freight, Inc. of Columbus, Ohio for the past nineteen years—serving as Vice President for the last fifteen.

He was the first elected President of the American Institute of Industrial Engineers, serving from 1948 to 1949.

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March 22: Youngstown Chapter Conference.

March 26–27: AMA Manufacturing Seminar.

March 29: Ninth Annual AIIE Conference on Work Simplification; Southern Hotel, Columbus, Ohio. Write Douglas Naehring, 28 E. Pacemont Road, Columbus, Ohio.

April 19: The Great Salt Lake Chapter Conference.

April 21–22: University of Chicago Automation, Operations Research and Business Planning Conference.

May 1: Fort Wayne Chapter Conference.

May 1–2: Cleveland Chapter Conference.

May 8–9: Fifth Annual Southeastern Regional AIIE Conference; Pensacola, Florida. Write Harley P. Macon, 1910 West Chase Street, Pensacola, Florida.

May 8–9: Symposium on Theory of Decision Processes; Purdue University. Sponsored by the Department of Industrial Engineering in cooperation with Departments of Mathematics, Statistics and Industrial Management. Write Dr. T. E. Bartlett, Heavilon Hall, Purdue University, Lafayette, Indiana.

June 1–6: Ninth Annual Industrial Research Conference; Columbia University, New York, N. Y. Write Robert T. Livingston, Director, Department of Industrial and Management Engineering, Columbia University, New York 27, N.Y.

June 16–July 26: Fifth Annual Southern Regional Graduate Summer Session in Statistics, Oklahoma State University, Stillwater, Oklahoma.

September, 1958: Fourth annual offering of the Engineering Executive Program starting in September; U.C.L.A. Write Engineering Executive Program, Department of Engineering, University of California, Los Angeles 24, Calif.

October 30–November 1: 1958 Northeastern Regional Conference, Syracuse, New York.

PERSONALITIES

JAMES M. APPLE

The establishment of a consulting business in the field of Industrial Engineering and Management has been announced by James M. Apple, former Professor of Industrial Engineering at Michigan State University. Mr. Apple had been at Michigan State University since 1947, and was in charge of the Industrial Engineering program. At Michigan State he organized the Annual Industrial Engineering Conference, and published the quarterly "M.S.U. Industrial Engineering News." He also served as a conference leader in the foremanship training program.

Prior to his work at Michigan State, Mr. Apple was a member of the staff of General Motors Institute for 6 years, where he developed executive training materials and served as a management conference leader. Mr. Apple is the author of the book, *Plant Layout and Materials Handling.* and has written widely in this field. He is also associate director of the Material Handling Training Conference held annually at the Lake Placid Club, and is director of the Plant Layout Technical Workshop held semi-anually in Pittsburgh, Pa.

Mr. Apple plans to specialize in custom-designed industrial training programs and in the general field of Industrial Engineering. In the past few years, he has done consulting work for many firms, including General Electric Co., Eagle-Ottawa Leather Co., Brunswick-Balke-Collender Co., Sealed-Power Corp., Dayton Malleable Iron Co., U. S. Department of the Army, etc. He is a member of the American Institute of Industrial Engineers, American Society of Mechanical Engineers, American Material Handling Society, and is a director of the Detroit chapter of the Society for the Advancement of Management. He is listed in *Who's Who in Engineering, Who's Who in Education, Who's Who in the Midwest* and in *Leaders in American Science.*

AKRON CHAPTER

The Akron Chapter began its 1957–58 year with a five weeks operations research symposium during September and October. The symposium, entitled "What Is Operations Research and How Can It Be Used in My Job," was presented by Mr. Walter Stapleford, O. R. Engineer, Thompson Products Inc., Cleveland, Ohio. The symposium was attended by fifty-one representatives from ten companies. It was a success both educationally and financially.

CALUMET CHAPTER

The 1956–1957 season was a highly successful one with all meetings well attended and committee assignments tackled with evident enthusiasm. Plans for an even bigger and better AIIE year were discussed at a board meeting held on September 10. Our two big special projects: the Community Chest studies, and the I.E. High School Counseling Project, are beginning to roll. Committees are formed and progress reports are most encouraging.

Our October meeting was held at Vogel's Restaurant, Whiting, Indiana, on October 8. A most interesting film entitled "SAGE" (Semi-Automatic Ground Environment defense system) was presented. This film, prepared by the Massachusetts Institute of Technology in cooperation with the Defense Department, dealt with the use of electronic computers for national defense.

Our November meeting took the form of a Ladies Night, and was held at the Gary Country Club. A program designed especially for the ladies was presented by Rev. Nelson Moore of the First Unitarian Church of Hobart. Rev. Moore gave a musical presentation of "The History of Popular Music in America." This presentation originated as a book review of Sigmund Spaeth's *History of Popular Music in America* given to a ladies organization, and was so well liked that he has been asked to give it at numerous other places.

Our chapter, to do its part in advancing Industrial Engineering, has taken as a special project the compiling and writing of a brochure especially designed to appeal to the graduating high school senior. In this way, we hope to advance our field and inform others of our aims and functions in industry. This brochure should be ready for presentation to the board of directors in the near future and finally at a regular chapter meeting. This material will be presented to P.T.A. organizations as well as to the various "College" and "University Nights" that are held in the area High Schools.

The December meeting was held on December 10 at Wilson's Restaurant in Gary, Indiana. Professor H. T. Amrine, Vice President of the Central Region of AIIE, spoke on "The Expanding Horizons of Industrial Engineering" and the part that

AIIE will play. The speaker was well qualified to talk on this subject since he is head of the Industrial Engineering Department at Purdue University. Prior to this position, he held the posts of Assistant Professor of Industrial Engineering and Associate Professor of Industrial Engineering at Purdue University.

CHICAGO CHAPTER

The September tour of the R. R. Donnelley and Sons Co. printing plant proved an outstanding success. Ninety-six guests were escorted through the three Chicago plants by ten guides from the Industrial Engineering groups. C. W. Lake, Jr., Vice President, welcomed the group in the Memorial Library after a dinner provided by the company. Al Wolski gave the group a briefing on the fundamentals of printing prior to the tour through the plant.

Jim Morrissey of A. T. Kearney discussed Office Standards at the October chapter meeting. In his discussion it was pointed out that office standards are becoming increasingly important as the ratio of white collar workers to factory workers increases. He advised that predetermined time standards are very expensive, but added that a modified form of work sampling has been quite useful and that the standard data approach is usually recommended as the best system for office standards. He gave examples of standard data which his company has developed for office operations. Mr. Morrissey stated that office standards have lagged behind manufacturing standards for several reasons. They are: the feeling that the prestige of white collar jobs would be lowered by the setting of standards, resistance of white collar people to have someone investigate their operations and the fact that office standards are frequently more difficult to develop than manufacturing standards.

The November meeting, held at the Western Society of Engineers, featured Jack Lanahan, Director of Business Procedures, Inland Steel Corporation. His subject was "Production Planning and Control Systems and Procedures." Mr. Lanahan was assisted by Earl Ryder, Superintendent of Business Procedures at the Inland Steel Indiana Harbor Works, in the presentation and discussion of Inland systems.

Mr. Lanahan received his B.S. at Princeton University and his master's degree at the University of Chicago. His experience with Inland has included the positions of Open Hearth General Foreman, Mill Provider Foreman, Assistant Manager of Works Accounting, and Manager of the Sales Department Order Division.

CINCINNATI CHAPTER

The first meeting of the 1957–1958 season was held Sept. 18, 1957 at the Engineering Society Headquarters.

Our guest speaker for the evening was Mr. Harry Hopkins a registered I.E. from Ohio State. He is also very active in many local Engineering Societies. In the years 1952, 1953 and 1954 he went to Austria, France and Turkey as a member on the Industrial Management Exchange Teams. At present Mr. Hopkins is Vice President of Manufacturing for Tool Steel Gear and Pinion Co. located in Cincinnati, Ohio. He gave a very humorous and enlightening talk on how to get things done through other people, a better relationship between technical and non technical people through a better means of communication.

The October meeting was also held at the Engineering Society Headquarters and consisted of a joint meeting with the American Society for Quality Control. Immediately after dinner all members enjoyed the coffee talk by Mr. Jack W. Levi, Jr., and Mr. Alfred Kuhn, the title "Arbitration—What it is and how it works." A theoretical case was presented after which each member was invited to a secret vote and it was later compared to the decision of the arbitrator, Mr. Alfred Kuhn.

After a short recess the group retired to the auditorium for our principal speaker Dr. Charles R. Hicks of Purdue University, who spoke on "Statistics Applied to Industrial Engineering." Doctor Hicks talked on experimental design in plastics and thermo plastic tooling for industry. He demonstrated the results of experiments at the university and the development formulae to be used to determine materials for tools in various industries.

The regular monthly meeting was held November 20, 1957 at the Cincinnati Engineering Society Headquarters.

The principal speaker was Prof. Frank Poland, Director of Education and training for National Steel Corp. and his subject was "Human Relations in Action." Mr. Poland has had wide experience in the fields of education and training, public relations, community organization and development. He has taken special training at Northwestern University, Pennsylvania College and the University of Chicago. Having spent the last 35 years with National Steel Corp. he gained both theoretical and practical knowledge of human behavior. Working with the University of Chicago Professor Poland developed a human relation program at Weirton Steel which is still in operation. Behavior in a person is caused—it can be developed to something either good or bad. With a good human relations program the individual can be motivated to the better ways of life.

CLEVELAND CHAPTER

Our December meeting was held on the fifth, at the Cleveland Hotel. Mr. Nyles V. Reinfeld, Managing Director of the National Institute of Management, was guest speaker. He chose for his subject, "Operations Research for Industrial Engineers."

Mr. Reinfeld not only has been a pioneer in successfully applying linear programming and other O.R. techniques to industrial problems, but also has simplified the language and methods of O.R. He has taught hundreds of engineers and other non-mathematicians with outstanding success. In this speech, Mr. Reinfeld described most of the O.R. techniques and fields of application. The group was exposed to several simple problems and their solutions. Distribution, product mix, machine loading, waiting line and inventory control applications were discussed.

The January meeting, also held at the Hotel Cleveland, featured Mr. K. T. Korn, Management Consultant, as guest speaker. "The Industrial Engineer at the Corporate Level" was the subject under discussion. Mr. Korn gave us some answers to the questions of how the Industrial Engineer can step from factory staff to higher levels, what he can do to bridge this chasm, and what some applications and techniques are that he should know to enhance his ability to make a more important contribution, as well as better his opportunities to be a top manager.

COLUMBUS CHAPTER

The October meeting of the Columbus Chapter of the AIIE was held in the Conference Room of the International Business Machine Company. Mr. John Lynch, Manager of Milling Machine Sales of the Cincinnati Milling Machine Company addressed the members and guests on "Machinery Replacement Programs."

On Tuesday, November 19, 1957, the AIIE sponsored a tour of the Newark Rod, Bar and Wire Works of Kaiser Aluminum and Chemical Corporation. This plant is the largest manufacturer of covered aluminum electrical conductor in the United States. The plant also produces rod and bar, extrusion ingots, screw machine stock, cable and wire of many types and sizes—welding screen and rivets. After the tour coffee was served and a movie shown in the plant cafeteria. The movie portrayed the growth of Kaiser in the aluminum industry.

Our first dinner meeting of the year was "Bosses Night." It was held on November 26, 1957, at the Grandview Inn. On "Bosses Night" each member is encouraged to bring along his supervisor as a guest. The reason for this is to enable us to better acquaint the management of local industry with our fine organization and its many functions.

Mr. Paul T. Shirar, Chief Industrial Engineer, of the Eaton Manufacturing Company, Cleveland, Ohio presented a very stimulating discussion on "Planning Electronic Data Processing Programs." Mr. Shirar pointed out that to start a program of this type we should first determine all needed and wanted data, set up a complete roadmap of a system to obtain these data and then select a machine with the proper capabilities to obtain the data. The economics of the system should not be by how many people it will reduce your payroll, but what information is required to do the job better.

The first meetings of the 1957–58 year for the Time Study and the Materials Handling special interest groups were held in October. These groups were originated in 1956 under the direction of John Roberts, then President of the Columbus Chapter, to enable all persons interested in these two basic fields of Industrial Engineering activity to discuss common problems informally.

The Materials Handling Group met October 30, 1957 at the Denison Engineering Company. Mr. Robert McCurdy, Regional Sales Manager of the Louden Machinery Company gave a very informative talk on "Batch Handling of Materials on Monorails."

The November meeting of this group was combined with the plant tour of Kaiser Aluminum.

The first meeting of the Time Study Group was held at the Jeffrey Manufacturing Company. Programs for future meetings were planned and "leveling films" from the Methods Engineering Council of Pittsburgh were shown and discussed.

On Wednesday, December 4, 1957 the Time Study Group met at the Westinghouse Electric Corporation. This program centered on specific causes of time standards grievances. Typical cases for discussion were presented through the mediums of skits, tape recordings and slides by representatives of Jeffrey Manufacturing Company, Ranco, Inc., and Westinghouse, who are well experienced in this type of labor relations. A panel was then formed by this group to entertain questions and discussions by the audience. Each panel member tried to present a distinctly different viewpoint when answering questions.

The Materials Handling Special Interest Group held a meeting December 18, 1957, at the Columbus Warehouse of Albers Colonial Stores. The speaker was Mr. Thomas W. McDowell, Division Manager of Warehousing and Transporation whose topic was "The Managing of Unit Bulk Warehousing Operations." The discussion included inventory control, space control and scheduling. After a question and answer period, tours were conducted through the warehouse, refrigeration plant, and produce plant. A very delicious buffet dinner was served by Albers Colonial Stores and Christmas gifts were given to all present.

The December meeting was held on Tuesday the 17th at Battelle Memorial Institute. Gordon B. Carson, National President of AIIE and Dean of the Engineering College, Ohio State University, addressed the group on "Frontiers of Industrial Engineering."

Mr. Carson stressed the need for local AIIE Chapters to keep their members up to date on all new Industrial Engineering Developments. His discussion also included the Industrial Engineer's place in the future and the changes which will be required in the education of the Industrial Engineer of the future.

DALLAS-FT. WORTH CHAPTER

"Long Range Company Planning" was the theme of a Technical Seminar held October 29 at the Hilton Hotel in Ft. Worth. General Chairman A. L. Ziegelmeyer led a hard working group in preparing an outstanding program, consisting of the following subjects.

Organizing for Long Range Planning—Mr. Lawrence L. Ellis, Partner, Booz, Allen, and Hamilton, Chicago.

Long Range Market Development—Dr. Jerry E. Drake, Professor of Marketing, Southern Methodist University, Dallas.

Long Range Planning, Manufacturing—Mr. Robert Luthi, Supervisor of Long Range Planning, Chance Vought Aircraft, Inc., Dallas.

Long Range Approach to Labor Relations—Mr. John Scott, Attorney, Samuels, Brown, Herman, and Scott, Ft. Worth.

Long Range Depreciation Policy—Mr. Paul T. Norton, Jr., Professor of Industrial Engineering, University of Florida, and Stanford

Long Range Company Finance—Mr. Paul E. Brodrick, Assistant to Vice President, Secretary and Treasurer, Dresser Industries, Inc., Dallas.

Dr. Lillian Gilbreth spoke at the Dinner meeting on "Automation," emphasizing the humanitarian aspects of the problems involved in the change to Automation. Her words were warmly received, and seemed a fitting closing to a day spent on planning for the future. After speaking to the group of 113 members, wives, and guests, Dr. Gilbreth installed the officers of the newly formed Ladies Auxiliary of the Dallas-Ft. Worth Chapter.

The Ladies Auxiliary is expected to be a valuable addition to the already closely associated group of Industrial Engineers in the Dallas-Ft. Worth area.

DAYTON CHAPTER

Our November meeting was held November 15 at the Standard Register Company, 626 Albany Street. Our speaker for the evening was James M. Apple, one of the relatively few accepted authorities on the subject of Plant Layout. Mr. Apple is author of the book, *Plant Layout and Materials Handling*, the Plant Layout section of the "Production Handbook" and many articles in the field of Industrial Engineering. He is currently an industrial management consultant and a lecturer in Industrial Engineering at Michigan State University.

The December meeting, held December 10 at the Duriron Company, 450 N. Findlay Street, dealt with the subject of "Role Playing for Developing Human Relations." Dr. James L. Green, Professor of Economics and Personnel Management, U. S. Air Force Institute, was featured speaker. Dr. Green first introduced the general subject, the fundamentals involved and what it means to Industrial Engineers. Then he conducted a role playing session with audience participation.

Dr. Green was well qualified to present this subject. He received his M.A. and Ph.D. (University of Minnesota) in Industrial Relations and Economics; he has taught the subject in several universities; and he has been a management consultant for four years. Dr. Green has just recently returned from Colombia, South America, where he was Economic Advisor to the Ministry of Finance.

DETROIT CHAPTER

Has the attendance at your regular Chapter meetings been up to desired expectations? If not, you might try a little extra publicity such as carried out by this chapter prior to the November meeting.

Percentage wise, based on total chapter membership, attendance at the meetings is good—about 25%. But, that isn't good enough. So, our membership chairman, Harry Brumback, with the assistance of his committee, composed two letters for mailing to about two hundred Industrial Engineers in the Detroit area who were not associated with the AIIE. The one letter stated several reasons why the recipient should become a member of the American Institute of Industrial Engineers. The second letter contained information regarding the coming meeting and extended an invitation to attend the meeting.

What were the results? A packed meeting to hear Chester Brisley speak on "Work Sampling As Applied to the Executive."

In addition to having a large attendance, several applications for membership were obtained and there were numerous requests for membership information and application forms.

Arrangements for the first Chapter Conference have been completed. The conference will be held January 23 and 24, at the Engineering Society of Detroit. Principal speakers are Messrs. *Phil Carroll*, *Paul Mulligan*, and *William Hodson*. The theme of the conference is Work Measurement, and it will cover such areas as Cost Control, Office Work and Maintenance. Detail information will be received by those in the Detroit area in the very near future.

GREAT SALT LAKE CHAPTER

The Great Salt Lake Chapter of AIIE in cooperation with the Mechanical Engineering Department of the University of Utah held their first Industrial Engineering seminar in the summer of 1957. The seminar drew several hundred people, was a financial success for the chapter, added a number of new members to the chapter, and most important of all increased the stature of Industrial Engineering in the area.

We thought you might appreciate reading something of the session and the factors we felt assured a fair degree of success. The seminar was certainly not the first rather successful regional or local seminar and not necessarily better than all others. Its significance, therefore, if it had significance, is due to this fact—the Salt Lake Chapter has only 60 members, considerably less than the average chapter, and the population of the general area is less than 250,000. Their success leaves little justification for a continued assumption that only the largest industrial centers such as Los Angeles, San Francisco, or St. Louis have chapters that should attempt regional seminars.

This group instituted plans for a regional seminar because they felt it would do three things for them:

(1) It would allow participation by busy managers and supervisors who would not have the time or inclination to take a week off for a national Industrial Engineering seminar.

(2) It would assist the younger engineer who frequently has the desire to attend a national convention but not the opportunity.

(3) It would allow the chapter to present to a broad audience outstanding men who are well versed in industrial problems and the specific applications of Industrial Engineering in the area.

The session consisted of a panel discussion, a luncheon and a luncheon speaker, two afternoon speakers and a dinner dance. The chapter was fortunate enough to be able to secure as panel participants four top men in Industrial Engineering in the state—a state that now includes large mining, steel, aircraft and equipment manufacturing organizations. In addition, the one-day session presented as major speakers two well known industrial managers and an exceedingly capable management consultant.

The panel discussion in the morning was informal in appearance but well planned in actuality. The discussion had been subdivided into twelve topics by mutual agreement of the panel members. Prior to the session each member of the panel submitted a written draft of possible comments on each subject to the moderator and the group spent a few hours with the moderator prior to the session. The result was an entertaining and informative discussion with touches of humor, heated debate, and cold facts.

The honored luncheon speaker, Mr. C. D. Michaelson, outlined the recent history of the mining industry and why he now felt that an industry which had been very slow to incorporate Industrial Engineering departments in its organizations must of necessity now utilize this function to its fullest extent. As an outstanding leader in the mining industry in this country and South America for the past twenty years, there is little doubt that his presence on the program went a long way in itself to assure the session's success.

Mr. Howard F. McCullough of General Electric forceably outlined the growing importance of maintenance in the national economy in his afternoon address and then emphasized the phase of productive maintenance concepts in this growing field. Mr. Thomas H. Martsloff of McKinsey and Company did an outstanding job of selling engineered standards. A fine speaker with an excellent grasp of his subject matter, it would be presumptuous to attempt to summarize his remarks in a few words.

LOS ANGELES CHAPTER

The December meeting featured Dr. R. R. O'Neil, Professor of Engineering at U.C.L.A. His topic was "Education for Operations Research." He told of the various courses U.C.L.A. offers in this interesting field, and also gave information on graduate engineering work being offered at U.C.L.A.

Our second speaker was Gene Beck, an automotive consultant, who gave a humorous discourse on the perils connected with the purchase of an automobile. Mr. Beck's talk included many inside facts not usually available to laymen.

Our January meeting featured a talk by Charles A. Bogenrief entitled, "An Approach to Cost Reduction for Indirect Labor." Mr. Bogenrief is Department Head of Industrial and Plant Engineering for the Grayson Controls Division of Robertshaw Fulton. The second attraction was a film by Rocketdyne, "Road to the Stars."

Arrangements for the ninth annual conference and convention of AIIE are gaining momentum under the leadership of Howard Dickason.

LOUISVILLE CHAPTER

Our October meeting was held at Bellarmine College on Wednesday, October 16. Dean R. C. Ernst of Speed Scientific School spoke on the subject, "Education of Engineers for 1970." In discussing today's educational system, Dean Ernst pointed out that our educational system is being controlled by 18th Century thinking. He expressed the belief that the technological advance of the last half of the century will be five to eight times as great as that of the first half of the century. He prophesied interplanetary travel, commercial use of atomic energy, and knowledge of the causes and cures of all major diseases.

The November meeting also was held at Bellarmine College. Mr. Tyler B. Williams, Chief of Consulting Branch of Ordnance Management Engineering Training Program, Rock Island Arsenal, spoke on "New Organization Analysis Techniques."

Mr. Williams defined organization as an association of individuals to accomplish a given objective. An organization analysis is the pattern of the design of the functions and people in the organization to assure the accomplishment of the predetermined objectives. He pointed out that an organization is continually changing. It does not exist in a vacuum. It is subject to internal and external pressures such as policy changes, political conditions, technological changes, methods, procedures, geographic problems, equipment, facilities, workload, manpower, and economic conditions.

MEMPHIS CHAPTER

The November meeting was held on Wednesday evening, November 20, at the Highland Heights Branch of the Union Planters Bank. Our distinguished speaker was Mr. Kurt Hinsch, Chief Industrial Engineer for the Kimberly-Clark Corporation in Neenah, Wisconsin. Mr. Hinsch's topic was "Photographic Work Sampling: A Case Study."

Our December meeting, held on the eighteenth, featured Mr. Harold Glen McMullen, Lighting Engineer of Memphis Light, Gas & Water Division, as main speaker. His topic was "Lighting, Seeing and Industrial Illumination." Mr. McMullen is a graduate of Mississippi State University where he earned his Bachelor of Science Degree in Power Distribution. He is the President of Mid-South Chapter of the Illuminating Engineering Society.

MIAMI CHAPTER

The September meeting was held at the University of Miami Campus. Mr. R. B. Roberts, Vice President of Florida Power and Light Co. stimulated the interest and enthusiasm of all chapter members with his dynamic presentation "The Future of Manufacturing in the Miami Area." He pointed out that the tremendous growth of diversified industry in Southeast Florida will create an increasing demand for technical personnel and in particular, The Industrial Engineer. Also during the evening Dr. J. P. Lesperance was presented a beautiful plaque in recognition of his fine leadership as past President of the Miami Chapter during the 1956–57 year.

The highlight of the October meeting was a talk "The Application of Computers in Industrial Engineering" given by Mr. Garret Fitzgibbons of I.B.M. Mr. Fitzgibbons is on special assignment at Eastern Air Lines. He discussed the types of computers available and stressed the increased use of this tool in solving management problems. Specific applications of the use of computers in the selection of site locations for sales outlets, setting up an inventory control, etc., were illustrated during his presentation. This was a very stimulating meeting with a good turnout of potential new members present.

The sixth annual Time and Motion Study and Management Conference sponsored by the University of Miami in cooperation with the Miami chapter of the American Institute of Industrial Engineers was held at the Columbus Hotel on Oct. 31–Nov. 1. The conference was a huge success. Among the registrants were several representatives from Industries in the Greater Miami area who expressed to Dr. J. P. Lesperance, Director of the conference, their keen interest and the continued need for these conferences. The topics covered and speakers participating in the conference were:

"How to Organize a Work Measurement Program in Retailing"—Mr. Harold Berger, Central Operations Manager, Burdine's Department Store.

"Management Decisions in a Business Enterprise"—Mr. Albert E. Bachmann, Management Consultant

"Industrial Engineering Applications in the Miami Area"—Mr. C. M. Kromp, Production Mgr., Panelfab Products, Inc.

"The Installation and Application of a Job Evaluation System"—Mr. R. K. Bradley, Manager Methods Dept., Owens Corning Fiberglas Corp.

"How to Organize a Methods Improvement Program"—Mr. Wm. Fitzpatrick, Industrial Engineer, Procter & Gamble

"Purpose & Significance of Executive Development Training Programs"—Dr. J. P. Lesperance, Director Motion & Time Laboratory, University of Miami.

"Training in Work Simplification"—Dr. S. Kyle Reed, Industrial Engineer, Union Carbide Nuclear Company.

OKLAHOMA CITY CHAPTER

Our October meeting featured Mr. Wayne Weeks, Personnel Development Supervisor for Southwestern Bell Telephone Co. of Oklahoma. "The Forward Look on Leadership" was the subject of Mr. Weeks' talk, who prefaced his remarks with the following story to illustrate the scope of the subject:

Two G.I.s came down out of the hills for the first time to an Army camp on the coast. The first remarked, "Man, that sure is a heap of ocean"; to which the second replied, "It sure is, and that's just the top of it."

Mr. Weeks frequent use of a flip chart to illustrate key points of his talk served to illustrate a part of the solution to one of the problems of successful leadership, that is the problem of communication between individuals.

Following an interesting and informative talk, Mr. Weeks showed the film, "The Eye of the Beholder."

For our November meeting, Dr. Randall T. Klemme, Director of the State Department of Commerce and Industry, will speak on "The Industrial Growth of Oklahoma."

First advance registrations for our Cost Control Clinic to be held in February were received in October from the Park-O-Meter Company of Oklahoma City who pre-paid registration fees for five of their key personnel. Interest being shown by other Oklahoma firms indicates that the Clinic will be well received.

PHILADELPHIA CHAPTER

Our third meeting of the current season was held at the Engineer's Club of Philadelphia on Wednesday, November 13. The speaker of the evening was Mr. Louis A. Ganz, Director of Executive Development and Organization of Food Fair Stores, Inc. He has been active in organizational development for many years and formerly specialized as a management consultant in organizational development and structure.

"Men at Work" was the title of Mr. Ganz's talk. He discussed the type of pressures that the business executive faces in his daily work and his reaction to these pressures both psychological and physical. Mr. Ganz deplored the present trend or cult of "practicing human relations." An individual's adult behavior is molded by his training in childhood. It is difficult if not impossible to make him over as an adult. In this regard, Mr. Ganz described "Executive Neurosis" the behavior symptoms of an individual who is placed in or seeking a top level position for which he is not qualified. Such symptoms are a prelude to either the physical or mental collapse of an executive.

Psychological tests for selecting future executives are merely indications of possible behavior but are not positive measures of how an individual will react when placed under pressure. One method of testing a potential executive is trial under actual conditions but this is costly. Hence the need for executive development programs.

In the opinion of Mr. Ganz, such programs are not restricted to large firms but should be adopted by smaller firms as well. In summary, Mr. Ganz indicated that executive training for the future is important. There will be significant problems to be faced 10–15 years from now. The increased size and age composition of our population will require different types of decisions to be made in the future in comparison to those of today. Such training may not be in the form of improving relations but rather more stress will be placed on courses in the humanities.

Despite the occurrence of an unexpected snow storm, the last meeting of 1957 was held on Wednesday, December 11. The subject under discussion was "Automation Through Electronics." The program consisted of two parts and was presented by Mr. John Nipp, manager of the Applied Science Division, and Mr. Dwight Collishaw, Manager of the Time Requirement Division of the I.B.M. Corporation of Philadelphia.

Mr. Nipp discussed the use of Electronic Computers. He described the nature of a digital computer and how it is controlled and operated. Mr. Nipp described the application of a digital computer to a production control system.

Mr. Collishaw discussed Integrated Data Processing in Automatic Data Collection. He indicated that industry is faced with a serious challenge in the field of industrial control and production control. There are many problems which require solution in these areas in order to catch up to the general level of automation now employed in the area of office automation or automatic data handling.

The approach necessary for an ultimate integrated system will require: 1. Collection of Data; 2. Analysis of Data (computations, etc.); 3. Comparison with Standards or Norms; 4. Complete the Loop and Effect a Control. Mr. Collishaw used a flannel board demonstration to describe APR (Automatic Production Recorder) equipment. This is the method developed by I.B.M. for automation production control. He reviewed applications for

APR covering. 1. Time Study; 2. Meat Packing; 3. Measurement and Testing; 4. Inventory Control.

A question and discussion period followed both meetings.

SOUTHERN TIER CHAPTER OF NEW YORK

At the September meeting of the Board of Directors, at the Statler Inn on the Cornell campus Harold May was made Director of Special Service Projects. The primary function of this project is to investigate the feasibility of providing Industrial Engineering assistance to the community.

Also, at this meeting, Prof. Byron Saunders of Cornell was appointed chairman of Professional Development. The purpose of this group will be to stimulate interest among the members in Professional Development through the submission of papers.

Mr. Carroll W. Boyce, lecturer and writer, presently with the *Factory Management Magazine*, was the principal speaker at the regular September meeting held at Cornell University. He holds a degree in Business and Engineering Administration from the Massachusetts Institute of Technology. He was consultant to the National Production Authority of the United States Department of Commerce. He has authored and co-authored several books and publications including "How to Plan Pensions" and "Material Handling Case Book."

His topic, "Challenge for Management" was presented with appropriate bits of wit and humor. The audience had a most pleasant time both learning and laughing concurrently. In essence, he said that many companies in a desire to get on the "Band Wagon" plunge headlong into Brainstorming, Linear Programming, the Queuing Theory, Operations Research, the Game Theory, etc., without fully investigating the application, the possibilities, and pitfalls inherent in each. He feels that each company should thoroughly investigate and study each application; it should make properly qualified people responsible for these techniques and the company should control the use of the results obtained from these methods.

Mr. Robert E. McGarrah, Program Chairman, and his committee have lined up a "banner array" of speakers for this season. The combination of interesting speakers and active projects are providing a real cohesive force in continuing growth of this chapter by promoting the organization's ideals and by providing a community service.

On October 24, 1957, Mr. J. Bruce Buckler, Manager of the General Education Program at the International Business Machines Corporation, Endicott, presented his "Gold Mine Between Your Ears." This was a lecture on Creative Thinking as applied to Industrial Engineering. Included in this lecture was an abundance of group participation. Mr. Buckler holds a master's degree from the University of Illinois in Educational Psychology and Visual Education. He is consultant advisor to the Creative Educational Foundation at Buffalo, New York, and has conducted workshop seminars at several universities.

TRI-CITIES, TENNESSEE CHAPTER

Our September 18 meeting was a "Get Acquainted Night." Mr. Sam W. Bartholomew, a member of the General Management Staff of Tenn. Eastman Co., and a former football star at the University of Tennessee, gave a "Southeastern Conference Pigskin Preview." Mr. Bartholomew is currently a member of the SEC officiating group.

September 30, October 21, we sponsored a refresher course preparatory to State Professional Registration examinations. Organized by Mr. Robert E. Lee, Tri-Cities, Tennessee Chapter member in charge of professional registration and a Registered Professional Industrial Engineer, the course covered in condensed form the broad range of Industrial Engineering subjects about which the examination would be concerned. Twenty-three members and non-members were enrolled and several of these have since applied for professional registration.

On November 20, Dr. Joseph J. Moder, Professor of Industrial Engineering, Georgia Institute of Technology, presented a talk on "Industrial Engineering, Operations Research and Inventory Control." Dr. Moder presented the fundamental concepts underlying Industrial Engineering, then discussed the contributions of Operations Research. He outlined the characteristics of Inventory Control as related to Operations Research, setting up and solving a typical Inventory Control problem.

At our December meeting, in addition to the election of officers, the Chapter viewed the Bellows Company, Inc. film entitled "Operation Push Button," a presentation of the use of controlled air power in industrial applications. Two of the Bellows Company representatives were present and, following the film, conducted an interesting question and answer period.

TWIN CITY CHAPTER

The December meeting of the Twin City Chapter of AIIE was a memorable one in the annals of the chapter. For the first time in our short 3½ year existence we went co-educational by inviting the ladies to a Christmas Party at one of the Twin Cities suburban supper clubs. It was a great opportunity for the wives to see what kind of professional colleagues their husbands had been associating with all these years.

Lest it sound as though frivolity was the theme of the occasion, let it quickly be said that the meeting had its serious aspect. Professor Gayle W. McElrath, Head, I. E. Div., U. of Minn. delivered a very learned and profound lecture on the subject of "Quality Control—Women's Oldest Weapon." The thesis of this lecture was that woman, throughout the ages has always been practicing the techniques and methodology of Statistical Quality Control whether she knew it or not—a point which he proceeded to prove systematically by analogy, to the huge delight of the entire group. And, whether we realized it or not, a few basic concepts of Statistical Quality Control also managed to slip in the back door.

WINSTON-SALEM CHAPTER

The opening meeting of the 1957–1958 season of the Winston-Salem Chapter of the AIIE was held September 22, 1957. Mr. Frank J. Johnson, National Director of Programs for AIIE and Manager, Production Engineering Design Analysis, Lockheed Aircraft, Marietta, Georgia, was the guest speaker. Mr. Johnson presented the subject "Producibility Analysis—A Challenge to Industrial Engineers," which is a new management tool using basic Industrial Engineering principles to reduce cost. The topic was approached relative to its use in the aircraft industry. It was brought out that considerable savings were effected by analysing systems, materials and design at the source, the preliminary design of the product. Work in this field enters into why a project costs what it does and what alternatives are available with the ultimate objective being an effective and economical product.

The second meeting of the season was held October 24, 1957. Guest speaker on the program was Mr. Fred A. Powell, Sales Representative for International Business Machines. Mr. Powell spoke on "The Use of Electronic Data Processing Equipment in the I. E. Field." Data processing equipment is now being used in industry for establishing standards and for production control.

The third meeting of 1957 was held November 26. Mr. N. A. Price, Jr., Management Consultant with Henderson, Lindsay and Michaels of Greenville, South Carolina, gave a talk on "Basic Motion Time Study." The importance of time study and other Industrial Engineering functions was emphasized by the statement "Man's progress depends much on how well he uses time."

TAX DEDUCTIONS INCURRED IN SOCIETY ACTIVITIES

The following information has been received by Engineers Joint Council, and confirmed by their legal counsel as being correct:

The Internal Revenue Service under ruling 55-4, I. R. B. 1955-1 states that a taxpayer "who gives his services gratuitously to an association, contributions to which are deductible" under the relevant provisions of the Code "and who incurs unreimbursed traveling expenses, including the cost of meals and lodging, while away from home in connection with the affairs of the association and at its direction may deduct the amount of such unreimbursed expenses in computing his net income"; subject, however, to the limitation in respect to all gifts made to exempt organizations of our type; namely, that the total amount of such gifts made in any one year may not exceed 20% of the donor's gross income for such year. This limitation means that while such expenses are deductible they are included with other gifts in computing the 20% limitation.

As the 1957 tax year is drawing to a close, it has been suggested that we publish the above paragraph for the information and assistance of our membership. It may be quite possible that certain individual members may have declined service on committees because of the additional personal expense, which they believed to be non-deductible.

DISTRICT INDUSTRIAL ENGINEER

Required at large Copper Mining Company, Chile, South America. B. S. or M. S. degree Industrial or Mechanical Engineering preferred with 5 years industrial engineering experience including 2 years supervisory capacity. Should be experienced in preparing method engineering reports, job descriptions, time studies, developing organization charts, etc. Salary $9,000, 3 year contract transportation both ways and salary while traveling paid by the Company. In reply give complete details.

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THIS practical working manual brings you step-by-step practices and procedures on all aspects of control engineering and design. You are guided every step of the way through system specification, synthesis and analysis, and evaluation. You get a complete run-down on pneumatic and mechanical control-function generators, servo wiring design, ac analog computers, and nonlinearities in control systems. Covers control systems engineering in both modern industry and the military, from the basic fundamentals to putting systems into actual practice.

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By L. R. Bittel, M. G. Melden, and R. S. Rice
Associate Editors, *Factory*

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This book clearly explains and illustrates fundamental methods and thinking essential to planning and setting up for effective automation. It shows how to solve problems likely to be met in installing automation—how to combine machines and equipment already in the shop—where to look for possibilities of applying feedback control—how to solve new maintenance problems and personnel problems associated with automation. In short, it guides you in every practical aspect of automation. Every major area of plant operation which is affected—including production, maintenance, cost control, administration, methods, and inventory—is covered in a really practical way.

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Will hold its

Ninth Annual Conference and Convention

on

Thursday, Friday & Saturday, June 12, 13 & 14, 1958

at

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Step through the gates to tomorrow's advancements in new ideas, new techniques and new equipment. The Industrial Engineer does, indeed, hold the key to increased productivity demanded by all manner of business today. But he must be alert to the challenge of his profession, he must be alive to the trends in the mathematical, physical and social sciences, and he must realize that only through interchange of knowledge can the individual keep pace and continually improve his position and earning power.

To this purpose is dedicated the Ninth Annual AIIE Conference. A wide range of subjects of vital interest to large and small operations alike shall be discussed by qualified and working authorities in each field—productivity in manufacturing, processing and service industries—administration of industrial engineering projects—product design, facilities utilization and planning, economic analysis of automatic production equipment, investment principles and profit control—advanced industrial engineering methodology—psychology applied to productivity.

SCHEDULE OF FEES

	Member	*Non-Member*
Full Conference This includes all sessions on Thursday & Friday and two luncheons and one banquet and proceedings. The convention luncheon on Saturday is *not* included.	$42.50	$53.50
Thursday Only (All Thursday sessions and one luncheon includes proceedings)	$24.50	$29.50
Thursday Luncheon Only	$ 7.00	$ 9.00
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Friday Luncheon Only	$ 7.00	$ 9.00
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Banquet Only (on Thursday)	$12.50	$15.00
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Ladies Program For the wives of full registrants. This includes the Thursday banquet and a full program of activities during the two days of the Conference.	$15.00	$15.00

NOTES:

1. Luncheon and banquet seatings can be guaranteed only if advanced registrations are made.
2. Checks are to be made payable to: "Ninth National AIIE Conference."
3. Refunds for cancelled reservations will be made only if notice is received prior to June 12, 1958. However, refunds for meals shall be made only if such request is made no later than the day preceding the meal.

Recent Readables

AUTOMATION

"Organizing for Electronics," by S. L. Shea, ADVANCED MANAGEMENT, *page 5.*

In trying to study electronic data processing and determining its probable effect and value, most companies will unconsciously or consciously follow these five major steps:

1. The start or initiation.
2. The backing of top management.
3. The establishment of a senior advisory.
4. The establishment of a working or survey group.
5. The intelligent use of the talents of these groups.

There is a tremendous amount of work to be done in getting ready to determine if electronics can be justified, which system it should be, what information need be obtained, and how it should be obtained and worked on. And this is only a start. Then comes the detailed "dog work" to set up a complex system and to install the electronic equipment so that it will do what we want when we want it.

It is quite possible that the cost of the study will be more than offset by the savings obtained by streamlining and house cleaning existing routines, even if a large electronic system cannot be justified.

COST CONTROL

"How to Plan for Lower Costs," by C. P. Hawkins, THE IRON AGE, *page 97, December 12, 1957.*

In any cost-cutting program management must know where to look first. Some areas will pay off immediately while others will yield lesser savings and take longer to analyze. In the first part of this article the author suggests six main areas for immediate cost cuts.

The second part of the article deals with setting up a sound cost control program. The author states that any cost-cutting program must be related to overall company needs. The first step is to determine what profit and cost components are—and how they relate to each other. From there on it's a matter of attacking specific areas for cost control.

In conclusion, five case histories are presented where the application of these principles have been successful.

"Cost-Control-Two-Way Radios Newest Bonus," by H. G. Weiss, MODERN MATERIALS HANDLING, *page 83, January 1958.*

Monsanto's integrated cost control system for materials handling—centering around the two-way radio dispatcher—has resulted in more materials handled at less cost per unit.

These savings resulted from better performance in four areas. Productivity and volume went up. Overtime was cut and unit cost came down.

Key man in the system is the radio dispatcher. Every request for materials handling service, whether it is to unload a freight car or transfer loaded pallets to outside storage, is telephoned to the dispatch center.

The dispatcher immediately makes out a ticket for each request, indicating when, where, and type of service required.

His second step is to sort his tickets. Vendor materials arriving by truck carrier and emergency transfers are handled at once. All others are processed within 24 hours.

He then sends the tickets to the department where the work is to be performed. When the transfer or receipt is complete, a clerk enters pounds received and man hours expended. The ticket is then returned to the dispatch center for further processing.

GENERAL

"Industrial Engineering Trends in 100 Plants, 1945–57," by The Editors, FACTORY MANAGEMENT AND MAINTENANCE, *page 140, October 1957.*

Dr. Ralph M. Barnes, alone with his colleague, Mr. J. L. McKenney, has just completed his third survey of Industrial Engineering. Most of the 80 companies which participated in the original 1945–46 survey are again included in this survey. This article tabulates the answers to eleven questions covering organization and personnel, methods and techniques, incentives, and training programs.

"Management Development," FACTORY MANAGEMENT AND MAINTENANCE, *page 91, December 1957.*

Management development is one of industry's newest tech niques. Plant executives expect it to work wonders yet this tool disappoints many companies who try it. In an attempt to point out pitfalls and to how management development can succeed, *Factory* offers 10 articles designed to guide these programs. These articles are:

1. Why Management Development Fails
2. Twenty-two Tips to Make Management Development Work
3. How to Handle Ticklish Problems
4. Picking Your New Supervisors
5. Redesigning the Supervisor's Job
6. Picking Managers by Ballot
7. New Way to Look at the Manager's Job
8. How to Handle "How Am I Doing?" Interviews
9. Taking the Measure of Your Managers
10. How to Create the Climate to Make Managers Grow

MATERIALS HANDLING

"Technics: A New Concept in Management," by R. G. Zilly, MODERN MATERIALS HANDLING, *page 109, December 1957.*

Simply defined, technics is "the coordination of the management arts to make the total plant operation more efficient and profitable through the medium of materials handling."

Some of the materials handling techniques it has actually put to work include:

1. Live storage at point of use.
2. Perimeter feed to production centers.
3. Overhead chain conveyor storage of both finished goods and production tools.
4. Bulk silo storage for finished components.
5. Inventory control at point of use.

It was born because one company discovered that every change in materials handling had far reaching effects on all phases of management. Materials handling, they decided, was the common denominator of good management. Wherever it was put to work it created the need for analyzing: materials purchase; inventory records; production planning; manufacturing methods; job ability of manpower; plant size; plant expansion—area, equipment, people; capital investment—raw materials, work in process, finished inventory; accounting procedure; selling price; industrial relations and safety; and competitive situation.

"How to Set Up an M-H Program," by R. G. Zilly, MODERN MATERIALS HANDLING, *page 105, December 1957.*

Based on experience gained by a management consultant, this article outlines a pattern that can be used by other companies. Realizing that the benefits of materials handling engineering had to be completely sold to the organization, and aware of the havoc that could result from a haphazard application of handling techniques, the following guideposts for a pilot project were set up by the consultant:

1. It must be a project in need of improvement from the viewpoint of timing and company good will.
2. It must be a package. That is, it must be isolated from other operations so that they will not be disturbed.
3. It must be a project that can be clearly outlined, accurately cost-estimated, and finished in a short time.
4. It must bring quick and clearly-demonstrable savings.

Also discussed in this article are:

1. How the materials handling program was oriented to company policy.
2. How it was integrated into the company organization.
3. What workable methods were developed for getting on with the job, and
4. How progress was kept track of.

"Switching: New Tool in Order Picking," by E. A. Funk, MODERN MATERIALS HANDLING, *page 86, January 1958.*

Carriers that switch from express to local conveyor guide tote boxes to predetermined stops. Thus the flexibility of power and free systems is applied to roller conveyors, and new efficiency is added to order picking.

The system consists of two parallel roller conveyors—one for express travel, the other for local order picking. Only one of these roller conveyors is powered. All orders travel down the powered conveyor, switching to the appropriate order-picking station by means of a preset mechanical code on the carriers.

A major departure from other systems is the use of angle-iron carriers to haul tote boxes singly and to lead any number of tote boxes or standard packages in trains. These carriers never leave the system. They perform a two-fold function: 1. Perform automatic switching by means of pivotal metal tabs which can be preset to trip electric switches at predetermined stations, and 2. provide a platform on which tote boxes are placed. When the switch at any station is actuated, the carrier is shunted to the local conveyor. The order picker at this station assembles the items and places them in the tote box. The carrier is then released and the process is repeated at successive scheduled stops until the order is progressively completed.

METHODS

"The Foremen and Productivity," by C. Zinck, ADVANCED MANAGEMENT, *page 12, January 1958.*

Every progressive manufacturing firm has a well-developed, company-wide, method, improvement program. It is staffed with full-time methods men who have the direct responsibility to increase productivity.

Foremen can also be important in the company-wide Method Improvement activity. Each foreman is in a unique position to assist those who have the direct responsibility to increase productivity, as well as to do Method Improvement work himself.

The foreman can assist directly the company-wide methods improvement program by methods improvements of his own. The techniques are simple, quickly learned and easily applied. He can tackle one activity after another through the use of the Written Record. He knows method improvement is part of his job, and will do effective work at it when trained.

The foreman will respond with worthwhile Method Improvements when Management sets up this as part of the responsibility of job as a foreman, and judges his contributions.

OPERATIONS RESEARCH

"Can You Profit from Operations Research?", by R. H. Eshelman, THE IRON AGE, *page 71, January 16, 1958.*

Managers need all the help they can get in making decisions on men, money, machines, materials and time. The promise of OR lies in raising a firm's batting average in making these decisions.

Tools Used—This effort to use the scientific method in business requires certain tools, usually mathematical. They include linear programming, statistics and probability, feed back control principles, queues or waiting lines, game and information theories, and electronic computers.

Steps in the actual procedure may involve:

1. Defining the problem—which is often different from the one you think you have.
2. Collecting data on factors affecting results. Analyzing all data and other information about problems.
3. Establishing a realistic yardstick for measuring results.
4. Developing models (often mathematical) to represent the system under study.
5. Testing each model on sample problems to make sure it represents the system accurately.
6. Developing working tools to achieve desired results. These should be simple enough for operating personnel to use in routine decisions.
7. Integrating the new methods into company operations.

ORGANIZATION

"The Logic of Organizational Planning," by T. F. Koch, MECHANICAL ENGINEERING, *page 840, September 1957.*

An organization exists because it is needed to do things its head is not doing. As an enterprise grows, people and machines are added to perform functions beyond the capacity of the head. He doesn't have the knowledge, he doesn't have the time, or it is simply more profitable to have some other person, or some machine, take over.

Organizational structure can come about in one of three ways:

1. The trial of various possibilities, discarding those that fail, and nurturing those that show signs of success. This may work well.
2. Allowing one or more dominant units to regulate their own relationships, thus creating the pattern to which others must conform. Sometimes this works well—until "dictatorship" sets in.
3. Planning the relationships for maximum utilization of the capabilities of each unit of the organization. In this way, most of the poor arrangements are eliminated on paper before they are tried, and any that do go into effect are watched so closely they have no chance to fail badly.

QUALITY CONTROL

"The Quality Manager and Quality Costs," by W. J. Masser, INDUSTRIAL QUALITY CONTROL, *page 5, October 1957.*

This article is devoted mainly to the costs related to assurance of product quality, because all industry is presently plagued with continuing pressure by customers for better and better quality products. And this pressure comes at a time when quality costs are at their highest level. Perhaps this high level exists because many businesses are operating with obsolete quality practices.

To develop the solution, the quality control manager must

become adept in analyzing the whole business cycle from the standpoint of quality effort and quality costs. To do this analysis there is a positive need for establishing quality objectives, quality goals, and quality programs that will assure the success of any planned quality control activity.

"Latent Reliability—An Approximation Method," by W. R. Davidson, INDUSTRIAL QUALITY CONTROL, *page 11, November 1957.*

This article as abstracted by the author defines "Latent Reliability" as a score describing the agreement between engineering predictions of end-item performance and actual performance. The method is designed solely for product development situations where costly units are destroyed by testing. The Latent Reliability score equates the pooled percent accuracy of performance forecasts on units $a, b, c, \cdots, k$ to the expected performance on the $(k+1)$th unit. Since there is no inherent requirement for extensive replication, the approach lends itself to experimental work where each test may result in design or process changes affecting the next test unit. Both the underlying rationale and the stepwise method of computation are presented.

WORK MEASUREMENT

"Direct Labor Requirement for Chemical Processes," by T. B. Haines, CHEMICAL ENGINEERING PROGRESS, *page 556, November 1957.*

Engineers in general, and chemical engineers in particular, at times become so interested in equipment, its design, function, maintenance, and the processes employing it that they tend to forget the human factor, namely manpower; at other times they completely overlook manpower's relationship to equipment operation, costs, profits, and the fact that for a given chemical process there is but one efficient manpower requirement. Either over- or undermanning makes for a lowered efficiency.

What constitutes a fair day's output or what an individual can actually accomplish without undue or injurious physical or mental strain is a manpower problem in the chemical manufacturing industry which, because of its wide variations, offers an extraordinary challenge to the techniques of Industrial Engineering.

"Industrial Standardization," Studies in Business Policy, No. 85, NATIONAL INDUSTRIAL CONFERENCE BOARD.

The Board abstract states:

Without standardization and simplification (the elimination of needless variation) the present level of American industrial efficiency could never have been reached.

Objections to creation of standards often stem from the preconception that the end result must be a deadly identity of products. It is true that the tool of standardization when misused can excessively restrict variety, retard innovation, and cripple the process of investing articles with esthetic or artistic values. But it is a fortunate fact that manufacturing standardization—which permits longer production runs, simpler tooling, faster production, better control of quality, and other productivity-increasing advantages—also permits industry to offer a richly varied array of goods.

In most of the companies that have formalized their standards work, the department or section is part of the engineering or technical staff.

In some companies design engineering functions are negligible and production problems are of primary concern. In these companies standards organizations are found as subdivisions of Industrial Engineering, methods engineering, or time-study departments under titles such as Work Standards, Standards and Methods, or Production Standards.

BOOKS

Analysis for Production Management, *by Edward G. Bowman and Robert B. Fetter, 1957, Richard D. Irwin, Inc., Homewood, Ill., $7.80.*

This text for the university student and the interested industrialist provides an analytical approach to economic problems of production management. The methods of analysis potentially useful in making economic decisions mostly involve mathematics and are organized in four major groups: orientation, mathematical programming, statistical analysis, and economic analysis. The authors use many examples including cases drawn from situations as illustrations.

Office Automation Applications, *by R. Hunt Brown, published by Automation Consultants, Inc., 155 Fifth Avenue, New York 10, $37.50.*

"To the systems man, office automation is a technique of more fully mechanizing office procedures," the author explains. "To management, office automation is a new management tool to simplify control of business, assist in decision making, lower operation costs, and speed up service to customers."

In the volume are sections describing methods employed in the field of office automation, case studies in industrial categories, a section on new management techniques, a summary, and an exhaustive index.

Covered are methods employed for feasibility studies, equipment evaluation, personal training, physical facility factors, basic programming, and advanced coding.

Management Bookshelf, *54 pages, Available on letterhead request from the American Management Association, 1515 Broadway, Times Square, New York 36, N. Y.*

This latest edition of the 1957–58 catalog contains a listing of all current AMA publications, periodicals, and films. Contents of series publications include AMA research and special reports. Contents of series publications appearing since 1955 are described, and titles are listed for those which appeared before 1955.

Film listings include a four-part series in full color and sound on data processing and computer systems and their significance to management.

Automation in Practice, *by S. E. Rusinoff, Illinois Institute of Technology; 261 pages, published by American Technical Society, 848 East 58th St., Chicago 37, Ill., $6.50.*

This book provides an integrated survey of latest automation techniques as applied to various manufacturing and metal-working processes. Emphasis is on practice, and material is treated in terms of processes rather than specific industries or products.

Automation is covered in terms of the three basic functions of production: materials handling, processing, and quality control. Major topics include basic principles relevant to manufacturing processes, implications of automation, and principles of feedback control loop with basic devices for effecting hydraulic, pneumatic, electric and electronic control functions.

A separate section covers particular manufacturing processes such as metal working, metal cutting, pressworking, joining, heat treating, casting, and production of ferrous and nonferrous metals.

Career Satisfactions of Professional Engineers in Industry, *84 pages, Available from the Professional Engineers Conference Board for Industry, 2029 K St. N. W., Washington 6, D. C.: $1.50 per copy to NSPE members, $3.00 per copy to nonmembers.*

This report presents findings based on interviews with professional engineers in industry. The purpose of the study was to examine the thinking of engineers at three different stages in their careers: Early, at 3 to 6 years' experience, midpoint, at 10 to 15

years' experience, and late, at 20 to 25 years' experience. Eleven companies in eight industries were included in the survey. Each company is among the top 200 largest corporations in the U. S., and each is a major employer of engineering talent.

Included in the report are experiences and backgrounds of engineers surveyed, their career outlooks, satisfactions and frustrations on the job, and values of the successful engineer.

Engineering Enrollment in the United States, *edited by N. N. Barish, N. Y. U. Press, 1957.*

Basic statistics presented and interpreted in the papers of 21 contributors. There are chapters on all major fields of engineering and one on engineering training in the USSR.

The Office in Transition, *by Esther Becker and Eugene F. Murphy, Harper, 1957.*

Puts automation into its proper framework in respect to a long term trend of mechanization. How various companies have successfully met the problems of automation forms the basis of the material in this book.

Engineering as a Career, *by Ralph J. Smith, McGraw-Hill Book Co., N. Y., 1956, 365 pages, $4.75.*

This book was primarily written for the freshman engineering student, but will be useful for counseling and guidance of prospective engineering students.

Work and Authority in Industry, *by Reinhard Bendix, John Wiley and Sons, Inc., N. Y., 1956, 466 pages, $7.50.*

Deals with the relations of men and with the question of the desirable structure and spirit of contemporary industrial civilization. In particular it is concerned with "managers" and "workers," and with the ideologies of the former, and with the authority-relation between employers and employees.

The Theory of Games and Linear Programming, *by S. Vajda, John Wiley & Sons, Inc., N. Y., 1956, 106 pages, $1.75.*

A brief and to-the-point presentation of linear programming and game theory fundamentals.

Games and Decisions: Introduction and Critical Survey, *by R. Duncan Luce and Howard Raiffa, John Wiley & Sons, Inc., N. Y., 1957, 509 pages, $8.75.*

Surveys the central ideas and results of game theory and related decision making models without making extensive use of excessive mathematical detail. It integrates recent developments noted previously only in the scattered literature. Aimed primarily toward those readers working in the behavioral sciences, the book emphasizes and criticizes aspects of the theories that appear to be of main concern to them.

Automatic Computers, *by Ned Chapin, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1957, 525 pages, $8.75.*

To know whether an automatic computer can be profitably used in your business, the computer's functions, uses and limitations must be thoroughly understood. This book is intended to convey just such knowledge and to point out how to obtain profitable use of an automatic computer in business situations. Included are comparative data on available models, including costs, definitions of special terms as they are introduced, discussion of major analysis techniques, examples, and many helpful illustrations.

Installing Electronic Data Processing Systems, *by Richard G. Canning, John Wiley & Sons, Inc., N. Y., 1957, 193 pages $6.00.*

Deals with the important, high-cost aspects of installing electronic data processing systems, covering the significant questions of fitting EDP into the organization, selecting and training EDP personnel, programming, physical installation of the system, and the early phases of operation. Studies of a number of companies in dissimilar fields have been synthesized into a single case history. It is written in non-technical language and assumes that the reader is relatively unacquainted with electronic computers.

Digital Computer Programming, *by D. D. McCracken, John Wiley & Sons, Inc., N. Y., 1957, 253 pages, $7.75.*

Written as a general introduction to the entire field, with emphasis on the basic principles. It is written for those with no previous knowledge of computing who want to know how to prepare the detailed "instructions" for the computer, as well as for people whose work is so closely related to computer applications that they need to know what is involved in programming.

Mathematics and Computers, *by George R. Stibitz and Jules A. Larrivee, McGraw-Hill Book Co., N. Y., 1957, 228 pages, $5.00.*

Computing devices and their components are described, especially the automatic digital computer, the way it works, and its capabilities and limitations. Non-digital computing devices are also covered. A treatment of the uses of randomness in computation, and typical applications of computing devices in Technology and business are covered.

Control Engineering Manual, *by Byron K. Ledgerwood, McGraw-Hill Book Co., N. Y., 189 pages, $7.50.*

Drawn from articles that appeared in *Control Engineering*, this book treats control systems in terms of the most up-to-date thinking of a number of specialists in the field, and covers everything from the basic fundamentals to putting control systems into actual practice. The material points out the many things that must be known about a process before it is possible to design a system to control it. After discussing a variety of typical processes, ranging from flying an airplane to generating steam, it analyzes tentative control system configurations by means of mathematical, trial and error, computer, and graphical techniques. Tests for the evaluation of a designed system are also included, and many practical examples are given. In addition, the book includes step-by-step design techniques for different types of control systems and tabular listings of control system function generating networks, plus basic information on analog computers and nonlinear techniques, and the use of combined analog and digital simulation in the design of control systems.

Principles of Mass and Flow Production, *by Frank G. Woollard, Philosophical Library, N. Y., 1954, 195 pages, $7.50.*

The author briefly traces the development of mass and flow production, presents 18 principles, stresses their application to both small and large production organizations, and discusses some of the problems of automation and the automatic factory of the future.

Automation: Its Purpose and Future, *by M. Pyke, Philosophical Library, N. Y., 1957, 191 pages, $10.00.*

The recent developments in controls and computers are bringing more applications of automation, and many more are likely to follow. The author discusses the development of the electronic computer, typical applications of automation in various industries, possible future applications, and the social implications surrounding automation.

opportunities

WHAT IT IS

The I.E. Opportunities service is a functional committee activity of the AIIE. Information concerning employment opportunit. s is collected on a nationwide basis and is provided without charge to members upon request. The committee is composed of members from the Columbus, Ohio chapter.

SERVICES PROVIDED

Current job openings are published in condensed form in each issue.

In addition, a monthly I. E. Opportunities Bulletin is supplied to over seventy chapters located throughout the United States.

Each job opening is assigned a "**P**" number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

EMPLOYERS

Employers having openings for qualified Industrial Engineers are invited to list them. Government agencies and educational institutions as well as business and industry are urged to take advantage of this free service.

Industrial Engineers are often employed in such fields as Work Measurement, Production Control, Plant Engineering, Operations Research, Industrial Relations, Sales, and Management. For a more complete coverage, see the following list of job classifications. Please do not hesitate to forward information on jobs in any area where it is recognized that an Industrial Engineering background will be of value.

To list your job openings with the Opportunities Service, send all or part of the following information with the name of your contact man to the address below: Type of industry, location, job classifications, minimum educational and experience qualifications, and salary range.

This information will be publicized to the members in condensed form in the JOURNAL and in monthly chapter Bulletins. Company names are not shown.

MEMBERS SEEKING JOB OPPORTUNITIES

The following list shows job openings available just prior to press time. If you would like more information about one or more of the positions listed, mail the "**P**" numbers with your name and address to the Opportunities Service at the address below. The Service will advise you by return mail of the name and address of the person to contact for further information, or advise you if the position is no longer available. Your name will not be forwarded to the company with the job opening.

For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

ADDRESS OF THE SERVICE

I. E. OPPORTUNITIES SERVICE
American Institute of Industrial Engineers
145 North High Street
Columbus 15, Ohio

INDUSTRIAL ENGINEERING OPPORTUNITIES

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range	
								from	to
1	Consult.	Ill	×	Broad			7–10	30	38
2	Education	Ga		51, 52, 31, 47		Ph.D.			
3	Prec. Mach. Shop	NY		94	10–12			35	45
6	Warehouse	NJ		94					
12	Steel Bldg. Mfg.	Ind							
17	Air Force	O		11, 13, 42, 31, 38	7.5–9		4–5		
20	Electric, Mfg.	Mo							
21	Education	Mass							
23	Education	NY		10, 30, 40, 52	6–10				
26	Education	NC				M.S.			
27	Education	Puerto Rico		37, 53, 31					
28	Education	Va		10, 20, 30, 40, 50, 60	4.2-6.0		2	25	35
29	Garment Mfg.	Northeast		37, 31					
31	Paper Mill	Wis		11, 45, 80, 70, 32			1–5		30
32	Rubber Products	O		40					
34	M. Consulting	O	×	30, 40, 53, 71			4	27	
39	Education	Neb							
41	M. Consulting	O	×	10, 21, 31			5–7		
42	Hospital	O		10	4.8–7.2				
49	Graphic Arts	Ill		11, 20, 42, 43, 70			3–5	25	35
58	Navy	Pa		10					
67	Army Ordnance	Pa			6.1–7.6				
71	M. Consulting	Ill	×	13, 21, 38, 42, 47, 70					
72	Airline	Ill		70, 42, 43					
75	Army Ord.	Ill		13, 31, 37, 70	7–9		2–4		
76	Trans.	Panama		48	9.5–				
79	Mining & Smelt	NM		10, 20, 30, 40			6–9.4		45
81	Chem. Process	O		38, 50, 11	6.0		0–5		19–30
83	Textile Co.	Ga		37, 42, 38	4.8–7.5				30
86	Public Utility	DC		10, 11, 13, 18, 37, 42, 43			2–3		
89	Foundry	Cal							
90	Education	Fla							

Position number	Industry, location		Travel?	Job classification number (See key)	Salary	Qualifications required			
					Range in $1,000	Adv. degree req.?	Years of exper.	Age range	
								from	to
91	Syn. Fibers & Films	Pa, Va, W Va		10, 20, 42, 43, 72			0–5		
93	Foundry	Ill		11, 19, 30					
106	Sugar	MD, La, SC, Conn		13, 43			0		
107	Aircraft	Wash		13, 30					
108	Consulting	Overseas	×	10, 20, 60			10	35	40
111	Chemical	Ala			7.5				
113	Chemicals	NJ		52					
114	Paper	Mo		11					
119	Paper	Ga		10, 20, 30, 42 43, 53	6.0–7.2				
123	Printing	NY		49, 53			2–4		
125	Chemical	Mich		13, 21, 43, 33			1–5		
131	Radiators	Md		44, 48	6.5–7.6				
132	Oil Seals	O		10, 20, 42, 45, 53	6.0		2–	25	30
136	Hospital	Pa		11, 63	6.0–8.0		2–		
137	Copper†	Chile, S A	×	31, 39, 43, 64	9.0		5–	30	
138	Wax	Wisc		11, 19, 42, 47, 81	5.9–6.9		2–4		
140	Magazine-Editorial	Mass		43	5.0–7.0				
141	Steam Electric Power	Toronto		93–80	11.0		13 (P.E.)	35	45
145	Lithography	Vt		31			2		
147	Paper & Bag Mfr.	Ala		10, 20, 35, 43, 54, 70					
155	Electronics	Texas		11, 13			3–		
156	Plastics	Texas							
163	Govnmt Inspection	O		37	6.4–7.5		7–		
164	Precision Mach Shop	Texas		11, 13, 19, 32, 42	6.0–7.2		3–5		35
165	Electro-Mechanical	Calif		11, 13, 19, 42, 53	5.8–		0–3		
166	Paper Mill	Pa		91–16			4–5		
167	Weapons Systems	Wash DC		50		Ph.D.			
168	Education	Mich		92	6.0–7.5	Ph.D./M.S.	1–5	25	55
169	Rubber & Plastics	Ind		10, 22, 23, 36, 42, 43	7.0		7–10		45
172	Power Shovels	Pa, Wisc, Ind		11, 13, 21, 32, 39					
173	Education	Pa.		19, 53, 51 (Research)	6.0–10.0	M.S./Ph.D.	1–5	30	45
174	Highway Dept.	Mich		11, 32, 38, 45, 70	5.3–7.1				
175	Printing	O		11, 13, 21, 36			2–		
176	Air Force	Ga		11, 18, 53, 71	5.3–7.5		0–		
177	Education	NY		50+General I.E.		M.S. or Ph.D.		30	45
178	Dietetic Foods	Ind		11, 13, 36, 52			0–4		
179	Education	Tex		I.E. Dept. Head		M.S. or Ph.D.			
181	Bldg. Maint.	Mich		31, 38, 48					
183	Metal. Fabr.	Ind		13, 21, 39, 42, 48	10.0	B.I.E.		30	40
184	Education	Pa		10, 47, 54, 81					
185	Chem. Plastics & Resins	Conn		50, 52, 37, 30, 36		M.S.	–5		30
186	Chem. Plastics & Resins	Conn		11, 26, 36			1–4		28
187	Glass	Tenn		43, 81					
188	Education	Mass		Asst. Prof. (50)	5.1–6.5	M.S. or Ph.D.			
189	Agric. Marketing	Maine	×	10, 42, 43, 53	7.5		2½		
190	Agric. Marketing	Wash. DC	×	10, 42, 43, 53	5.3		½		
191	Agric. Marketing	Wash. DC		10, 42, 43, 53	5.3		½		
192	Air Force Base	Ala		11, 13, 15, 16	4.5–7.5			18	
193	Pharmaceuticals	Ind		13, 21, 42, 44, 50, 55, 70	5.4				
194	Airline	Cal		11, 31, 36, 42, 43, 45, 71	8–12				
195	Consult.	NJ		10, 20, 31, 42, 54, 70	8–12	B.S.	5	30	45
196	Navy	Pa	×	13, 33, 42	7.4		2½		
197	Aircraft	Wash		I. E.	5–10		2	25	40
198	Paper Converting	Mo		13, 19	6–		5	30	40

† 3 yr contract.

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement
12	Suggestion Systems
13	Work Measurement and Perf. Stds.
14	Stop Watch Time Study
15	Std. Time Data Dev. & Applic.
16	Predeter. Elemental Time Stds.
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non-Prod. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organization Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

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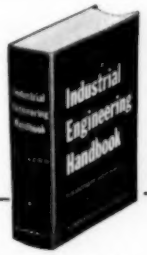

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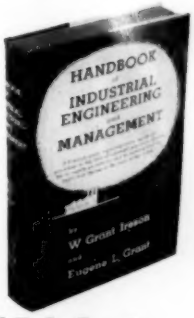

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